Preparing Risk Assessments for ChemistryProject Work in Schools & Colleges

Revised

Foreword

The HSC booklet "COSHH: guidance for schools", published in 1989 outlined a way by which schools and non-advanced FE colleges could implement COSHH. It was a useful publication but it did not cater for project work.

The principles used here can be applied however to any novel or project work.

Outline

Sections 1 and 2 of this booklet outline possible strategies by which it is possible to manage the business of carrying out assessments and set in place measures needed to adequately control risks to health.

Some teachers and employers may be concerned that Advance Higher pupils do not always have a teacher in their immediate presence when working on a project. Discussions with HSE inspectors resulted in the reasonable compromise outlined in Section 3.

Sections 4 to 8 describes a method which is suitable for carrying out and recording risk assessments. A worked example for a chemistry project is included.

The intrinsic hazard of a particular chemical will be the same regardless of where it is used and usually the risks to health are similar. However a few specialised activities carried out in other subject rooms, such as physics labs or technology classrooms, will sometimes use the chemicals in very different ways. In technology departments, for instance, chemicals such as solvents and varnishes are likely to be used in quantities significantly larger than in a chemistry laboratory and processes are more likely to take place in the open workshop rather than using a fume cupboard.

Authorship

The preparation of the first edition this booklet was principally the responsibility of Allen Cochrane, Depute Director of SSERC at the time, without whose work this publication would not exist. The revision, as with much of SSERC's work, has been a team effort.

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1 Introduction

The purpose of this publication is to help employers, and those to whom they have delegated responsibility, with the preparation of assessments for novel practical activities.

Existing Assessments

To allay fears we should emphasise right away that virtually all of the practical work for standard courses in science departments can be covered by referral to existing general assessments. These can be found from several sources, especially the SSERC website.

Projects

Project work has long been a lynchpin of the Advanced Higher and the ability of pupils to go 'off-piste' wherever their interest takes them is one of the important features of the courses.

Usually most, and often all, of the steps within most projects can be covered by use of the general assessments used for regular class-based experiment. Sometimes, however, pupils propose project work which involves more obscure reagents or techniques. It would be all too easy to reject these out of hand and thereby lose interesting and educationally valuable activities. One of the objectives of this booklet is to show that making assessments is seldom difficult and, like driving a car, it becomes more automatic with time.

The last version of this guide was entitled 'Preparing COSHH risk assessments for project work in schools'. COSHH is still extant and arguably the most important single piece of legislation affecting working with chemicals. It is not the only one however: DSEAR (the Dangerous Substances and Explosive Atmospheres Regulations 2002) for example deals with flammables and explosives and so is greatly relevant to almost all organic chemistry work.

Beyond that, there are other risks (and concomitant pieces of legislation) associated with practical work, such as electrical safety, optical radiation, ionising radiation and microbiological hazards.

While investigative work will often fall easily within the one subject sphere (biology, chemistry or physics), it is quite common that several areas are covered. Electrolysis and electrophoresis, for example, have electrical hazards as well as the chemical and biological ones.

It is SSERC's advice that, rather than conduct separate risk assessments under COSHH, DSEAR etc, a single risk assessment be assembled covering all the relevant hazards.

A broad overview of risk assessment was given in SSERC Bulletin 213 (Winter 2004). This may be a few years old but the advice therein is still sound. However, this issue concentrated mainly on 'simple' assessments and how to latch on to an existing 'standard' or general assessment.

For the more complex or unusual procedures that may be encountered in project work, the risk assessment, or at least part of it will need to be started from scratch.

Carrying out an assessment from first principles means looking at how substances are used and then making a judgement on the possible risks to health arising from such usage. If these risks are unacceptable, then adequate control measures (precautions) must be set up.

The Law requires that:

(i) assessments are made of the risks posed by carrying out experimental procedures which may be hazardous to health and that

(ii) control measures are implemented which will prevent or, where that is not reasonably practicable, adequately reduce exposure to them.

(a) Using general risk assessments

There already exists a large number of general risk assessments which cover the bulk of practical activities in school science departments. Employers have the choice of either

(i) adopting, and if necessary adapting these to their own particular circumstancesfor practical work in science

or

(ii) making their own assessments.

When making these (or other) risk assessments, there are two especially useful sources of information:

- **Hazardous Chemicals database (SSERC)** (and other parts of the SSERC website)
- **Topics in Safety (ASE)**

These two publications contain, for the most part, the results or conclusions of risk assessments rather than the details of the assessment processes themselves. Thus the precautions needed to prevent exposure of school staff and pupils to substances hazardous to health are given for the bulk of practical activities carried out in school science.

If a large number of schools in a particular Education Authority are following the same practical text or pupil resource, a simple route is to prepare centrally one set of general assessments (using appropriate reference materials) and issue these to schools. This applies equally to bought-in commercially-written materials or materials produced in-house.

All the activities published on the SSERC website come with a general risk assessment based on the HSE 5-Steps model. So if you are faced with the task of creating a risk assessment for

a new activity, it is worthwhile seeing if SSERC has details, and a risk assessment on the website.

Even if the SSERC website does not have anything specific to that activity, there may well be useful information for similar activities that you can adapt.

(b) Novel risk assessments in science and other subjects

Activities such as those likely to be found in project work, especially in Science and Technology classes and at Advanced Higher level, may not yet have ready-made general assessments to lean on. For these cases it is essential to prepare a ‘made to measure’ assessment **before starting any work**. (See sections 4 -8)

2 Implementing risk assessments

It is essential that pupils (or teachers) do not to start on any practical activity of a novel type. i.e. one for which no prior assessments exist, until a suitable and sufficient assessment has been completed and recorded in an appropriate fashion.

The question arises as to who prepares the assessment.

As part of the Advanced Higher, the pupil is expected to carry out a risk assessment of the processes involved in his or her project.

This risk assessment **must**, however, be checked by the responsible teacher **before** the practical work commences.

Once the pupil has done the preliminary work, the best approach is for teacher and pupil together to prepare the risk assessment for the activity, using the method described later in this document. This option has a number of benefits:

- pupil and teacher are more involved in the thinking about the project. Additionally this has an educational value for the pupil who is going to enter a world of work where risk assessments are an integral part of the operations..
- a preliminary assessment often indicates that many, or perhaps all, of the steps or sub-tasks can be covered by adaptation of existing generalised assessments. In this fortunate case you will only have to record the existence of those general assessments to show that the activity had been considered and to write the required control measures into the proposed project scheme. On the other hand this initial assessment may show that there is no substitute for a particularly hazardous substance and time can then be more fruitfully spent seeking an alternative reagent or analytical method.

If it turns out that the procedures being proposed are quite novel and the teacher is unfamiliar with the risks associated with reagents and procedures, he/she should seek advice from a senior colleague, Local Authority adviser or SSERC.

3 Supervision of project work

It is recognised that senior students can, subject to certain conditions, be allowed to carry out practical work without the teacher always being present in the same room, Those conditions are:

- the students are mature, responsible and have sufficient experience and training

- the possible risks have been identified and the ways of removing or adequately controlling them have been planned in advance. While the risk assessment may be carried out by the pupil, it must be thoroughly checked by the teacher before any experimental work begins.

- the teacher should be present during any stages which are considered to be of more than low risk. At other times he/she is usually in an adjoining room. Supervision ‘at an oscillating distance’ can be seen as an important part of a system of controls

While any system should have a certain degree of flexibility in it, situations such as one we came across where a student was sent in by the teacher to carry on with project work during a school holiday, apparently with no thought given to supervision, are entirely unacceptable.

Technicians

There are many technicians up and down the country who are not only highly capable but also actively enjoy assisting with project work. In a situation such as this, everyone benefits.

However, the support to be provided should be measured against the competence of technician staff in the subject area, in consultation with their immediate line manager, and the prioritisation of other work within the department – just because an individual technician might be keen to be involved, does not mean that it is the best use of his/her time in the department.

However it must be noted that the teacher has sole responsibility for the supervision of project work activities undertaken by the student and cannot delegate this responsibility to technician staff.

If a technician is not happy to be involved with the monitoring of this project work, whether this be due to workload, concern about their own competence regarding a particular procedure or any other reason, they **must** not be placed under any duress to do so.

Access to chemicals

Any requisition of chemicals for project work by a pupil must be approved by a teacher.

It is not good practice to give out a stock bottles of a reagent. In the case of hazardous chemicals, larger quantities could lead to more serious consequences should an accident occur. Also, with the best will in the world, it increases the chance of contamination and if there are several students using the same reagents it can create frustration and annoyance which could lead to other difficulties.

The best option is for the technician to prepare bottles/jars of the reagents that the students requisition at the beginning of their project which are then the 'property' of that student for the duration of the work.

We then come to the question of storage and access. It is unlikely that an Advanced Higher project will be confined to the use of chemicals that are all of such low hazard that they can be kept in the laboratory. So more secure storage is called for.

Although it may seem that the easiest way for students to get the chemicals for their project work would be to allow then free access to the chemical store, this is not an acceptable option. Even trustworthy students can make mistakes and have accidents and, perhaps more to the point, this option would seem to be in breach of the Home Office guidance as set out in the leaflet 'Secure Your Chemicals'.

On the other hand, getting students to ask the teacher or technician every time they need to get hold of any reagent is going to be excessively difficult and frustrating; particularly for the technicians and particularly in a large school with a lot of advanced higher students.

If the facilities allow it, a compromise may be sought. If there is more than one storage area, the low-hazard chemicals that the students have requisitioned for their project work could be kept in one of them, with the high hazard substances remaining in the chemical store. If not, then possibly the low hazard substances (dilute acids and the like) could be kept in the prep room, or some other secure area and the high hazard ones remain in the chemical store to be handed out by technicians. It should be emphasised that safety must always take precedence over convenience. Thus while it may be deemed appropriate to allow freer access to less dangerous chemicals. a more formal requisition form would be appropriate for any chemicals with significant hazards.

It is for the school (or Local Authority) to come up with a solution that blends security and convenience in an appropriate manner.

The storage arrangements, where they differ from the normal storage arrangements, must obviously be risk assessed. Whether this is included as part of each student's risk assessment or whether there is a generic, departmental risk assessment for the storage of chemicals for project work is, again, for the centre to decide.

Training

It is essential that, before any practical work is undertaken by a student, they are familiar with any techniques they might be using so that:

- They will be able to carry out practical work safely
- They will be able to carry out practical work effectively and accurately.

If it is a procedure the student has previously carried out in class, the teacher must check with the student that they are familiar with, for instance, the procedure for setting up apparatus for refluxing and, if not, have a brief reminder session.

If it is a novel procedure for the student, more thorough training, provided by the teacher concerned, will probably be needed.

Before carrying out any hazardous step of the project, the apparatus should be checked by the teacher. For example to ensure that in a distillation the clips or stands are in place to hold the apparatus together securely.

4 Making the assessment

There are a few difficulties in making a risk assessment from scratch that present themselves from the outset.

- Unlike ongoing industrial processes, for school projects the activity has not yet taken place, and may well never have taken place in the school before, so the assessor has to try to visualise the details of the planned steps and processes and to focus in on the likely weak points of the activity.
- Some processes used in projects may involve non-standard materials of variable or even unknown composition, examples being ores which are to be analysed, by-products from industry, water or soil samples from particular environments.
- For a small number of such substances it will be difficult to identify the hazards. Other processes, whilst they are new to schools, are well tried elsewhere in industrial or academic research; help and advice is readily available from persons working in those sectors.
- By definition, all of the steps in research cannot be known in advance. Often, as initial results come in, the need for work along lines not originally envisaged may arise. That bridge can be crossed as it appears and, if necessary, a further assessment then made. For obvious reasons it is wise to prepare the risk assessment before ordering any chemicals or equipment required for the process.

The previous version of this document, published in 1999, used two different forms, one for micro-organisms and one for other risks.

Since then, we have revised our risk assessment procedures and now recommend that all risks be assessed using the HSE's 5-Step approach. This is discussed in more detail in chapters 5 – 7 with a blank form on p 27 and an example risk assessment for a project in Ch 9.

The 5 steps are:

1. Identify the hazards
2. Decide who might be harmed and how
3. Evaluate the risks and decide on precaution
4. Record your findings and implement them
5. Review your assessment and update if necessary

From the point of view of actually producing a risk assessment for a new activity, it is the first three steps that concern us most.

Use of generic risk assessments

As will be seen in the next section, there are many potential hazards that might affect your project. Many of them, however, will not be directly related to the particular work you are doing or are common procedures that are in widespread use.

> *For example, distillation is a common process that has certain hazards associated with it. The glassware (and some other equipment) will get hot, if left to boil dry, flasks can break, if not fixed properly the apparatus can fall apart (potentially spilling hazardous chemicals) etc.*

There should be a standard procedure for setting up and using apparatus for a distillation and as long as the pupil has been trained in and is adhering to that, there is no need to mention anything more about the process except where the nature of the chemicals used may make a difference.

> *For example, if you are distilling a flammable substance, you should not use a direct flame. If there is the possibility of toxic fumes coming off the distillation should be carried out in a fume cupboard. These hazards should be recorded.*

The sorts of procedures for which there should be generic procedures and risk assessment might include:

- Handling chemicals (weighing, decanting measuring etc)
- Using laboratory equipment (quickfit glassware, centrifuges, lights, power supplies etc)
- Manual handling
- Slips, trips and falls
- Violence, lone working, etc

If a section of your experiment has already been risk assessed, you do not need to do the risk assessment all over again. For example, refluxing – unless the substance being refluxed has particular, properties that would suggest a new risk assessment be put in place.

5 What are the Hazards?

Collect information about hazards from suitable sources (SSERC website, msds etc.)

Remember to consider end-products, intermediates and by-products.

Focus on the significant hazards.

The first thing to do is to gather all the information you can about the hazards involved in the various stages of the project. At this stage, it is best that **all** chemicals and equipment should be listed.

There is no need to use the 5-Step recording form for this initial, information gathering, stage. The information can be recorded here in any form that seems appropriate. The important thing is to go through the whole of the process and list all of the potential hazards and their natures.

As well as the starting materials, consider the products and he on the look-out for any unintended harmful by-products, e.g. arsine which may he formed accidentally by having, present with an arsenic compound, a reducing agent in acidic conditions. (Several examples are included in Appendix 2).

Consider also intermediate and final compounds which, though not isolated, can pose a hazard during the process of the reaction.

Remember that the same substance may be encountered in different forms, quantities or concentrations as it is used in successive steps. Consequently each of these steps will have to be individually assessed as though a different material were being handled in each case. For instance solid sodium hydroxide and 0.4 M sodium hydroxide solution

Remember, too, much advance preparation of materials is on a larger scale where bulk chemicals and concentrated solutions are broken down from bulk or diluted. These situations are more hazardous that small scale use of diluted reagents.

Disposal must also be considered.

Significant and insignificant hazards

Once you get into the habit of looking out for hazards, you will see that there are an awful lot of them. The table below gives a list of most of the categories of hazard you will come across – though it does not claim to be exhaustive.

Chemical Hazards			
Toxic / harmful	***Corrosive/irritant***	***Flammable***	***Explosive***
Pyrophoric	***Oxidising***	***Water reactive***	***Carcinogenic***
Mutagenic	***Reproductive toxins***	***Specific target organ toxins***	***Environmental hazards***
Dusts			
Biological hazards			
Pathogenic micro-organisms	***enzymes***	***zoonosis***	***Animal bites/ scratches /stings***
Plant stings etc			
Physics hazards			
Ionising Radiation	***Optical radiation***	***electricity***	
Technology hazards			
Tools / equipment	***Machinery***	***Noise or Vibration***	***High Pressure***
Miscellaneous hazards			
Fall of objects	***Fall of Person***	***Tripping / Slipping***	***Manual handling***
Glassware and other sharp objects	***Hot / Cold Surfaces***	***Mobile work equipment***	***Repetitive strain injury***
Display screen equipment	***Lighting***	***Temperature / weather***	***Psychological effects***
Housekeeping / waste materials	***Mechanical lifting equipment***	***Violence***	***Drowning***
Workstation – layout / space	***Confined space***	***Lone working***	***Buildings & glazing***

You will soon find that you have an enormous number of entries on your list and it is clear not all these are significant hazards. So what do you leave out?

a. Water (as a chemical reagent at least) is entirely harmless. While it may cause a slippage hazard if spilled, unless the procedure is likely to lead to a significant amount of water spilled on the floor, this eventuality can be ignored.

b. Other substances such as chalk, salt and sugar are also harmless and can be ignored. Be aware, however, that even if there is no chemical hazard, all sorts of substances which are otherwise harmless can become hazardous as dusts.
c. Most pieces of electrical equipment. Things such as kettles, lamps, water baths, hotplates, power supplies. There should be appropriate procedures and risk assessments for handling these pieces of equipment but they do not need to be re-written on every risk assessment. It is assumed that they are handled and operated safely. If you feel this is insufficient, a statement in the 'Additional Comments' section of the risk assessment sheet can be inserted. Something along the lines of; 'Electrical devices (list if necessary) should be within PAT test and handled according to standard procedures.
d. Many lights (any device covered by the optical radiation guidelines for instance) will need to be included, (lasers, uv lamps etc) but a normal lamp – such as used for illuminating dye-sensitised solar cells need not be.
e. Most pieces of glassware. As above, there should be standard procedures and risk assessments for distillation, reflux etc and these can simply be referred to if needed. Likewise any possibility of harm from broken glass or pushing a thermometer into a cork. These activities are more general and detailed risk assessments do not need to be recorded here.
f. Most manual handling – the school should have a generic risk assessment for manual handling so, unless there are special circumstances, it is assumed that any heavy items are moved according to proper procedures. Handling need only be mentioned if there is something specific involved.
g. The same applies for other non-specific hazards such as use of display screen equipment.

Classification of chemicals

At the time of writing, the implementation of the new, GHS/CLP classification system is almost complete. Chemical preparations used in technology may still use the old CHIP classification labels for the next year or two. (Until June 2017)

An additional confusion is that, for the many chemicals which do not have 'harmonised' classifications, there is the possibility of the same chemical having a different classification depending on which supplier it is purchased from.

Details of GHS/CLP and of its implementation can be found in Appendix 13.

Chemical Hazards and concentration

It is clear that the hazards associated with chemicals changes with concentration. Pure ethanol is highly flammable, a glass of prosecco is not.

Under the new GHS classification of chemicals, the change in hazard class with concentration is given either as:

1. A specific limit for a particular substance eg sodium tetraborate (borax) is a reproductive toxin at concentrations of 8.5% and above.

   These figures can be found on the SSERC website or, if the substance is not listed there, on the SDS or the ECHA database.

Or

2. A generic limit eg a substance which as an Acute Toxin Category 3 by ingestion will become Category 4 below 33% and cease to be classified at all below 5%.

   These figures too can be found on the SSERC website or, if the substance is not listed there, in the GHS documentation . [1](In the case of a chemical not being listed on the SSERC website, contact us and we will remedy the situation).

Chemical Hazards in Technology

Technology classes will be using fewer substances that chemistry, but often on a larger scale and in a way where they are not so easily contained. For example, the large area of a freshly varnished workpiece will give off a high level of solvent vapour.

Processes generating wood dusts in general are not covered here in detail since the problems and the required methods of control are well known. They should, however, be included in any risk assessment. Sometimes the only way of knowing that adequate control is being provided is to proceed with the work and carry out some monitoring exercises. If the face velocity for an LEV on a saw bench was measured at the same time that the wood dust levels were found by personal monitoring to be significantly below the WEL of 5 mg m^{-3}, then in future only the simpler measurement of face velocity is needed in order to be assured that the dust levels remain satisfactory. That assumes, of course, that the kind and scale of activity will be similar. This sort of extrapolation could be extended to other rooms, possibly even in another school, provided that conditions are similar. Other activities such as welding and casting can be dealt with in a similar way.

EH40 and exposure limits

Many substances are hazardous to health by inhalation, volatile organic compounds for instance. In this case they may be assigned a Workplace Exposure Limit (WEL)[2].

These limits are listed in the document EH40[3]

There are two different WELs listed (though not always): a Time Weighted Average (TWA) exposure, usually over 8 hours (sometimes referred to as a Long Term Exposure Limit, LTEL), and a Short Term Exposure Limit, STEL, usually over 15 minutes.

If a substance is regarded as being 'hazardous to health' solely because of its inclusion in EH40, this clearly implies that the main route of entry into the body is via inhalation. The appropriate controls would be to reduce the levels of vapour or dust generated- use smaller scale, lower temperatures or use suitable local exhaust ventilation (LEV) to capture the airborne contaminant. Some substances

[1] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:353:0001:1355:en:PDF (this runs to 1355 pages so think carefully before printing it out!)

[2] European Law uses Indicative Occupational Exposure Limit Values (IOELVs). For substances assigned IOELVs, Member states are required to establish their own national exposure limits. In most cases, the Brithsh limit will benthe same as the European one, or very close to it.

[3] http://www.hse.gov.uk/pubns/priced/eh40.pdf

are assigned a ‘sk’ (skin) notation which means that they are also readily absorbed through the skin. For these, further precautions should be taken to eliminate or greatly reduce entry by this route.

Most substances listed in EH40 are vapours from volatiles and gases. Others which are quite easy to handle safely in their usual, solid or crystalline forms are also listed here if in the form of fine dusts, e.g., barium sulphate, nickel salts, dichromates(Vl) and sucrose.

It is hard to see how dust levels of such compounds approaching the WELs (i.e. LTEL or STEL) might be created in a school laboratory.

Providing adequate control for a substance with a WEL means not only avoiding exceeding this level when averaged over the stated reference period (8 hours or 15 minutes), but also reducing it as far as possible below that level. Clearly if the exposure only lasts for say 30 minutes, then averaging over 8 hours will enormously reduce the time weighted average. An occasional excursion above the LTEL is not indicative of a failure to maintain adequate control.

Some substances, which give rise to acute effects, have a 15 minute referenced WEL (a STEL). This should never be exceeded.

For substances not assigned a STEL it is recommended that a figure of three times the 8 hour time weighted average (TWA) limit is used as a guideline for controlling short-lived excursions.

For substances assigned an WEL, exposure should be reduced to that level. However with exposures above that level control can still be deemed adequate, provided the problem is recognised and plans to reduce the contamination levels are in hand.

As far as a school laboratory goes, Appendix 6 gives details of how to calculate the concentrations of airborne contaminants.

If this figure is one tenth or less of the value of the Workplace Exposure Limit (LTEL or STEL) the process can be carried out in an open room, if not, a fume cupboard is required. Figures need only be approximate and can be rounded up or down

6. Who might be harmed and how

Consider all the people who may come into contact with the hazards you have identified, especially technicians.

Consider routes of exposure for these people.

WHO?

There are various people who may be at risk from the hazards relating to project work: most obviously the person or persons carrying out the practical work: a pupilmor student.

But it is important to consider others as well;

a. **Technicians** - as they are likely to be responsible for most of the preparation are likely to be at greater risk.e.g:

   If an experiment calls for 1M sulphuric acid, it is the technician who will need to dilute this from the concentrated acid and thus will face grater hazards

   For microbiological work, technicians are more likely to be exposed to agar dust while preparing plates.

   If a substance is used in different forms and/or concentrations, (as discussed under 5 Hazards), different people may be at risk in different ways. For instance, a technician handling concentrated (.880) ammonia is facing different hazards from a pupil handling a 1M ammonia solution.

b. **Supervisors** – if the supervisor (most likely a teacher) is close to the practical work, be aware that they may not be focussing on it as closely as the pupil is. They should wear suitable protective equipment, if appropriate, and be alerted when any more hazardous section of the procedure is being carried out.
c. **Fellow pupils** – there may well be fellow pupils carrying out their own investigations in the same room. They are likely to be unaware of the hazards involved in your project so make sure they are warned of anything that may cause them harm and that, if they are in close proximity, they are wearing appropriate protective equipment.
d. **Other people** – There are not many other categories of people to consider but two to think about are visitors to the laboratory and cleaning staff. While their safety should certainly be considered, there is unlikely to be any need to include explicit reference to them in the risk assessment. There should be standard procedures for cleaning staff in science labs in your school or college and as long as pupils. teachers and technicians follow their parts in these – perhaps by making sure machinery such a fume cupboard is labelled to ensure it is not switched off overnight if it is needed – all will be fine.

Be particularly aware of the possibility of harm to technicians and others during clearing up and disposal

HOW?

How harm can arise will vary with the particular hazard being discussed.

For instance, harm from an electric shock can only come about if the 'vicitm' is in contact with (or at least very close to) the electrical apparatus. Whereas damage to the eye from a laser can happen at a significant distance.

For chemicals, there are three main routes of exposure:

Ingestion – It is very unlikely that any chemicals will be ingested in the laboratory deliberately but carelessness can lead to accidental exposure by this route. Eating or drinking in the laboratory risks contamination and should thus not be allowed under any circumstances. More likely, poor attention to hygiene can lead to contamination outwith the laboratory. A failure to wash hands after handling toxic chemicals can easily result in poisoning.

Dermal absorption – some substances are easily absorbed through the skin and can then cause systemic damage rather than just local damage such as caused by corrosives. In cases like this, measures should be put in place to eliminate, as far as possibly, any skin contact. If gloves are worn, care should be taken to ensure they are the right type (see Appendix 9)

Inhalation – This is the most likely route of exposure for most chemicals. All schools will have access to LEV in the form of fume cupboards so if a chemical is significantly harmful by inhalation, it should be handled thus.

7. Evaluate the risks and decide on precautions

Consider whether the risk is low enough to allow the procedure to take place.

If it is not in its present form, consider what adjustments to the method might be needed. (Use of a different chemical, reduction of scale, use of LEV etc)

This needs to be done for each of the cases ensuing from the information gathering in sections 5 and 6 (above).

In order to decide on the appropriate precautions, you need to look at the hazards, assess the likely exposure and evaluate the risk. This is the hardest part of the exercise.

The two questions to ask are:

1. How great is the hazard?

For instance

> *Potassium cyanide is a category 1 acute toxin by skin contact, potassium fluoride is an acute toxin category 3 by skin contact. It is clear to see that the former is a significantly greater hazard than the latter.*

2. What is the likelihood of exposure?

For instance.

> *Ammonia and sodium hydroxide are both corrosive.*
>
> *Sodium hydroxide, however, is a solid while ammonia is a gas.*
>
> *Sodium hydroxide can be safely handled (with appropriate care and precautions) in the open lab, while ammonia, if generated in more than very small amounts, should be handled in a fume cupboard.*

The **risk associated with a process** can usually be reduced dramatically in a number of ways. Here is a list of different methods for controlling risk, in decreasing order of preference.

Elimination / Substitution	Don't carry out the task / use the chemical. Use a different method / reagent etc. *For example – if your procedure calls for chloroform as a solvent, it is very likely that you can successfully use cyclohexane as a solvent* *If you are investigating enzyme inhibition by cyanides, can you use a different inhibitor (mercury salts work for many but are also toxic – though less so) perhaps you can use a different enzyme that is inhibited by less harmful chemicals.*

If your experiment calls for a laser, would a less hazardous light source fit the bill instead.

It is very strongly recommended that, where possible, a carcinogen, or other chemical which produces a serious and irreversible risk to health, should be substituted with a less hazardous one. (See appendix 4)

Where possible great care should be taken to avoid the use of sensitisers. (See appendix 5).

Paradoxically, in some cases a smaller risk will be posed by using a more toxic material if it is considerably less volatile and the main routes of body intake are via inhalation.

It is often easy to substitute one solvent by another of lower toxicity, but to forget about the possibility of accidentally producing reactive incompatible mixtures.

For example, replacing tetrachloromethane by propanone is generally a sensible idea but as a solvent for bromine it can result in a violent reaction.

If there are no suitable substitutions that can be made, it may well be the case that the experiment should not be done at all in the form under review.

Engineering Controls

Enclose area to avoid human contact, reduce scale.

A common example of enclosing the area is use of a fume cupboard. This will obviously render a procedure safer but do not forget the movement to and from the fume cupboard as an opportunity for exposure. Safer does not mean without risk at all..

It is good practice to reduce in general the scale of much practical work where possible. Not only does it mean that the amount of exposure to harmful substances is greatly reduced, there are substantial savings in cost of materials and disposal of waste products as well.

For instance, many azo compounds are carcinogenic. It will, however, often be difficult to find toxicological data for the precise compounds generated in many experiments.

However, if done on a micro-scale, the quantities generated are in the microgram range and the final solution is disposed of immediately after use so as long as sensible precautions are taken, there is no problem with the procedure.

Work Organisation	Reduce number affected / duration of exposure, guard machinery etc.)
	These procedures should be in place as a matter of course. The number potentially affected is going to be small anyway, the exposure should always be kept to a minimum and machinery should have all appropriate guards fitted..
Training,	Supervision, safe systems of work.
	For supervision, see section 3. Safe systems of work should already be in place. Pupils should only undertake practical work that they have had adequate training in order to carry out safely.
PPE	Use as a last resort.
	Make sure that any PPE is appropriate for the task intended.
	For gloves, see Appendix 9
	For Eye Protection, see Appendix 10

As **VERY** general guidance,

1. Consider elimination / substitution or, in extreme cases, changing the practical altogether if

   - any chemicals involved are category 1 acute toxins

   - any chemicals involved are explosive

   - any chemicals involved are category 1 carcinogens, mutagens, reproductive toxins or specific target organ toxins

   That is not to say that any practical using these should immediately be abandoned but they should be looked at very carefully.

2. If there are airborne hazards, (fumes, vapour, dust etc), unless the hazard is very low then engineering solutions should be considered such as using a fume cupboard.

3. When considering airborne hazards, be aware of the likelihood of them arising.

   For example:

   In an experiment where the nickel content of a salt is being determined colorimetrically,

   Most nickel compounds are carcinogenic, reproductive toxins and acute toxins, particularly by inhalation. The potentially most hazardous step, therefore, is the weighing out and preparing the solution: accidental inhalation of dust would give rise to the biggest risk to health.

   Since the method is an analytical one, the salt is going to be weighed out and handled so that none of it is accidentally spilled.

Once in the fairly dilute solution, the risk from handling a few cm^3 is negligible.

and

Phenol[4] is toxic (Cat 3) by inhalation (as well as being corrosive and a mutagen) so should generally be handled in a fume cupboard. If phenol solution is being used for a diazotization reaction in testing for nitrates (III) (Nitrites) the concentration and quantities are so small that the tests can safely be carried on a bench in the open lab as long as the room is well ventilated and the testing is not going on for too long.

Appendix 11 describes a semi-quantitative method (very similar to that used in the original 1991 edition of this guide) which can be used to help assess the risks involved in a process.

Numerical values are assigned to hazard and possible exposure and a calculation produces a risk index.

This method may be of use for some people to **assist** in informing their judgement but we would stress that no such algorithmic method (of which there are several) is foolproof. The calculated risk index should **only be used as a guide to assist the overall assessment.**

For example, the method given would suggest that preparing a solution of sodium hydroxide should be carried out in a fume cupboard whereas experience and common sense would suggest that there is no need for this precaution at all.

Hazards and Risks of volatile substances

Sometimes the above method of estimating the hazard of a volatile substance, and hence of the risk may not seem to be sufficiently accurate. A simple calculation of the concentration of vapour produced and a comparison with the WELs may sometimes be preferable.

This approach, which is expanded in Appendix 5, is quite suitable for those substances described in EH40 and not in the ECHA database. Methods of calculation and ready-reckoner tables are presented in Appendix 5. One advantage of this method is that the length of time of the process is considered. Thus it will answer the question "For how long can a particular process be carried out in an open laboratory or workshop?"

[4] Phenol is banned for use in schools by some Local Authorities. If this is the case for you then you are bound to follow the authority's advice.

8. Record your findings

Contrary to what some health and safety professionals would have you believe, there is no specific form that you have to use to record the result of your risk assessment, whether it be undertaken under COSHH or any other piece of legislation.

That said, if your authority prescribes a certain format for risk assessments then you are bound to use that format.

A long, complicated form to fill out is likely to be counterproductive. Risk assessments may not be carried out as carefully and they are certainly unlikely to be read as carefully if it is too complex and time-consuming.

> *One example we saw recently required a 4-page document for each chemical (or class of chemical) used: the risk assessment for our biodiesel experiment which, using our 5-step template, covers 2 sides of A4 needed 24 pages in this format, without adding to the safety of anyone following it.*

A sample form, that we use at SSERC, for the HSE 5-step approach is shown over the page.

The format should work perfectly well for project work, though it would be a sensible idea to add in, probably at the end, a section for a signature of the person who carried out the risk assessment and the person who checked/authorised it.

SSERC Risk Assessment (revised version November 2009)

(based on HSE '5 steps to risk assessment')

2 Pitreavie Court, South Pitreavie Business Park, Dunfermline KY11 8UB
tel : 01383 626070 fax : 01383 842793
e-mail : sts@sserc.org.uk web : www.sserc.org.uk

Activity assessed	
Date of assessment	
*Date of review (**Step 5**)*	
School	
Department	

Step 1	Step 2	Step 3		Step 4		
List Significant hazards here:	*Who might be harmed and how?*	*What are you already doing?*	*What further action is needed?*	*Action by whom?*	*Action by when?*	*Done*

Description of activity:

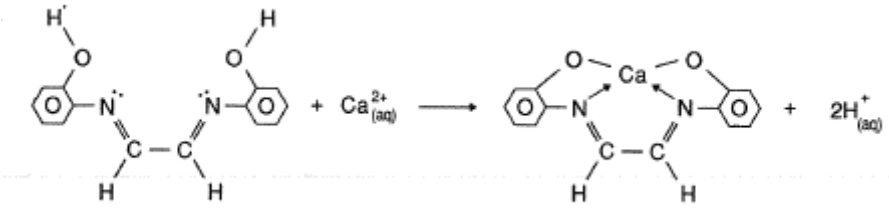
Additional comments:

9 Worked example for a chemistry project

In order to illustrate the principles of risk assessment an example is given of an analytical method proposed for a sixth year project.. A somewhat difficult example has been chosen deliberately. This is because the difficulties posed – incomplete toxicological data etc. - are likely to be occasionally met with in practice.

i) Description of the project

One of the main activities in this project is the determination of calcium with glyoxal bis(2-hydroxyanil) (GBHA), systematic name di(2-hydroxyphenylirnino)-ethane. This colorimetric technique is more sensitive than the commonly used complexiметric titration with EDTA. The details of the technique had been found in the School Science Review, (March 1988). and had been reproduced from an earlier article in Analytica Chim. Acta.



At pH 12.5 the reagent forms a water insoluble complex with calcium ions. This complex is, however, soluble in several organic solvents and the intensity of the pink colour can be measured in a colorimeter or spectrophotometer.

Reagents

Reagent solution 0.5 g of GBHA is dissolved in 100 cm^3 of methanol

Buffer solution 10 g of sodium hydroxide and 10 g of disodium tetraborate are dissolved in deionised water and made up to 1000 cm^3

Solvent Mix equal volumes of ethanol and butan-l-ol. say 50 cm^3

Standard calcium solutions

Prepare a stock solution by dissolving 1 g of AR calcium carbonate in 25 cm^3 of 1M hydrochloric acid and making up to 1000 cm^3 with deionised water. Diluting a further 100 fold gives a 0.0001M solution with respect to Ca ions

Method

Prepare known concentrations of Ca ions in the range 0 to 10^{-4} molar (or 40 μg per 10 cm^3) by further dilution.

Transfer separately 10, 20, 30, 40, 50, 60, 70, 80 and 90 cm^3 of diluted stock solution into 100 cm^3 flasks and make up to 100 cm^3 with water.

To 10 cm^3 of each of these standard solutions add 1 cm^3 of buffer , 0.5 cm^3 of reagent followed by 10 cm^3 of solvent . Shake in a small stoppered flask, leave for 30 minutes, place in a 10 mm path cuvette and measure the absorbance of the pink solution using Ilford filter no 604 or at 520 nm if using a spectrophotometer. Use deionised water as a blank. The colour is stable for at least an hour.

Repeat, with the sample. the procedure carried out on the standard solutions.

ii) Assessment of hazards

a) GBHA solution

According to the Sigma Aldrich SDS, GBHA has the following hazards H315 Causes skin irritation, H319 Causes serious eye irritation, H335 May cause respiratory irritation. It is thus of fairly low hazard.

Methanol is highly flammable (Cat 1), acutely toxic (Cat 3 by ingestion, inhalation or skin contact) and is a specific target organ toxin for eyes in particular.

b) Buffer solution

Solid sodium hydroxide is corrosive (Cat 1A) Solid sodium tetraborate and solutions over 8.5% are a reproductive toxin (Cat 1A)

The buffer solution, at 1% is a Skin/Eye irritant (Cat 2)

c) Solvent

Ethanol is highly flammable (Cat 2),

Butan-1-ol is flammable (Cat 3), Acute toxin cat 4 (oral), Skin irritant Cat 2, causes eye damage Cat 1 and is a respiratory irritant. It is damaging to eyes and can be readily absorbed through the skin.

d) Calcium solutions

1M Hydrochloric acid is of low hazard.

Calcium carbonate is of low hazard (but be aware of dust).

Calcium chloride is irritant at 10% and above

iii) Who might be harmed?

The technician will be exposed to greater hazards when making up the GHBA and buffer solutions and the ethanol/butanol solvent.

iv) The Risk Assessment

Using the information in the previous section it is possible now to assess the risks involved in each step

A completed risk assessment form for this investigation can be found on the following pages, with a discussion of significant points afterwards.

SSERC Risk Assessment (revised version November 2009)
(based on HSE '5 steps to risk assessment')

2 Pitreavie Court, South Pitreavie Business Park, Dunfermline KY11 8UB
tel : 01383 626070 fax : 01383 842793
e-mail : sts@sserc.org.uk web : www.sserc.org.uk

Activity assessed	Determination of calcium using GHBA
Date of assessment	3rd July 2013
*Date of review (**Step 5**)*	
School	
Department	

Step 1	Step 2	Step 3		Step 4		
List Significant hazards here:	*Who might be harmed and how?*	*What are you already doing?*	*What further action is needed?*	*Action by whom?*	*Action by when?*	*Done*
a) preparing GHBA solution GHBA is a skin/eye & respiratory irritant. Methanol is highly flammable, toxic (Cat 3) by ingestion, inhalation & skin contact and is particularly damaging to eyes	Technician – preparing solution – by splashes or inhalation of fumes	Wear goggles (BS EN166 3) and gloves (rubber/plastic) Prepare solution in a fume cupboard. Keep away from all sources of ignition.				
b) preparing buffer solution Sodium hydroxide is corrosive and sodium tetraborate is a reproductive toxin	Technician – preparing solution – by skin/eye contact or inhalation of dust	Wear goggles (BS EN166 3) and gloves. Avoid raising dust				
c) preparing solvent ethanol is highly flammable. Butan-1-ol is flammable, harmful by ingestion, a skin/respiratory irritant and causes eye damage	Technician – preparing solution – by splashes or inhalation of fumes	Wear goggles (BS EN166 3) and nitrile gloves. Prepare solution in a fume cupboard. Keep away from all sources of ignition.				

Step 1	Step 2	Step 3		Step 4		
d) preparing calcium solutions No significant hazard		Avoid raising calcium carbonate dust while preparing.				
e) carrying out experiment GHBA reagent is flammable and toxic (due to methanol) The buffer solution is a skin/eye irritant The solvent is flammable, harmful by ingestion, a skin/respiratory irritant and causes eye damage	Pupil – using solutions – by splashing or exposure to fumes.	Wear goggles (BS EN166 3) and gloves. Work in a well-ventilated area and well away from any sources of ignition. Re-stopper reagent bottles and flasks immediately after use to minimize fumes.				

Description of activity:

Reagents

Reagent solution 0.5 g of GBHA is dissolved in 100 cm^3 of methanol -

Buffer solution 10 g of sodium hydroxide and 10 g of disodium tetraborate are dissolved in deionised water and made up to 1000 cm^3-

Solvent Mix equal volumes of ethanol and butan-l-ol. say 50 cm^3-

Standard calcium solutions Prepare a stock solution by dissolving 1 g of AR calcium carbonate in 25 cm^3 of 1M hydrochloric acid and making up to 1000cm^3 with deionised water. Diluting a further 100 fold gives a 0.0001M solution with respect to Ca ions

Method

Prepare known concentrations of Ca ions in the range 0 to 10^{-4} molar (or 40 µg per 10 cm^3) by further dilution.

To 10 cm^3 of each of these standard solutions add 1 cm^3 of buffer , 0.5 cm^3 of reagent followed by 10 cm^3 of solvent . Shake in a small stoppered flask, leave for 30 mins, place in a 10 mm path cuvette and measure the absorbance of the pink solution using Ilford filter no 604 or at 520 nm if using a spectrophotometer. Use deionised water as a blank. The colour is stable for at least an hour.

Repeat, with the sample. the procedure carried out on the standard solutions

Additional comments:

While it is the case that both the GHBA solution and the solvent solution give off hazardous fumes, a combination of fairly small quantities, brief exposure and dilution with calcium solutions (which will reduce the vapour pressure) means that it is possible to carry out this reaction in the open lab as long as it is well ventilated.

Discussion

1. Substitution of Reagents.

The hierarchy of preferred control measures (listed in full in para 32 (Reg. 7) of the COSHH Approved Code of Practice)[5], and repeated in shortened form here, starts with elimination, substitution, and runs through engineering controls, LEV and right down to personal protective equipment as the least preferred option

There are a couple of significant risks here so the questions should be asked:

a) Is ethanol a suitable alternative to methanol as a solvent for GHBA?

b) Is there a suitable alternative to butan-1-ol for the solvent mixture? Butan-2-ol for instance is slightly less harmful.

2. Handling corrosives

Some algorithmic approaches, such as that used in the last edition of this publication, can suggest that a fume cupboard should be used for preparing the sodium hydroxide solution Nevertheless the relatively small scale employed (preparation, at most, of 1 to 2 dm^{-3}), the wearing of eye protection. gloves and a labcoat combined with the use of good laboratory technique will ensure that the worker is adequately protected.

The fume cupboard or other special cabinet will thus only be needed for handling corrosives

- where they are volatile liquids or concentrated solutions of gases (e.g. ammonia or amines) or in the form of aerosols or fine dusts which are being suspended in the air[6] (e.g. calcium oxide used in a respirometer, dust-free granular soda lime should be used in this situation.)

and the scale is other than small.

Making a solution of sulphuric acid by dilution of the concentrated form would not require the use of a fume cupboard. On the other hand an anodising process, which generates an aerosol of sulphuric acid droplets, would need to be done in a fume cupboard if carried out on a large scale for a lengthy period of time. However a fume cupboard would be needed if a volatile or a readily disseminated substance were also toxic in an acute or systemic sense or at some more distant target organ, regardless of whether or not it was also corrosive, e.g. chromium (Vl) dichloride dioxide (chromyl chloride).

3. The product of the reaction Ca - GBHA complex

No information is available on this material. However the quantity produced for one reading is very small – less than 1mg per cuvette and it is disposed of immediately. Wearing of gloves will provide adequate control.

4. Complete information on the hazards may not be immediately available. At the time of publication of the first edition of this document, there were there are no risk phrases (Hazard Statements) for GHBA, nor was there a control limit in EH40.

[5] The COSHH regulations and accompanying ACOP and Guidance can be downloaded from the HSE website here: http://www.hse.gov.uk/pubns/books/l5.htm

[6] Such materials can obviously reach into the lungs and destroy the delicate tissue there.

While it is now covered under the GHS classification, it serves as a good example of how to approach the use of a chemical for which such information is not available.

Searches in occupational hygiene libraries showed that at the time GHBA had not even been classified by RTECS (Registry of Toxic Chemical Substances). RTECS contains information which has been gleaned from all reports and papers and which has often not been substantiated by others. The only information in the catalogue was the word 'Irritant'.

The SDS sent on request by the supplier contained the following information of interest. Under the heading of *acute effects* it is stated:

- to be harmful by inhalation, ingestion or by skin absorption and to be irritating to the eyes, skin and mucous membranes and upper respiratory tract

- that to the best of their knowledge, the chemical, physical and toxicological properties have not been thoroughly investigated.

Other information possibly useful in deciding on the type of control measures included the following:

- the material is in powder form and has a melting point of 220°C

- is incompatible with strong oxidising agents

- the steps to be taken in the event of a spillage are to wear respirator. chemical safety goggles, rubber boots and heavy rubber gloves; to sweep up, place in a bag for waste disposal and to avoid raising dust.

This advice sounds as if it is intended for industrial users, i.e. the manufacturing and packaging processes rather than for the use of a less than a gramme as an analytical reagent. The technical inquiries department confirmed this suspicion verbally. The same department also stated that if GBHA is used as in the method described above there should be no problems. This leaves us perhaps a little better off than the situation of conclusion v (Nature of hazards unknown so cannot decide about risks).

From here there can be two main ways forward.

i) substitute the reagent with an alternative. Examine the projected work again and ask if the lower sensitivity of an EDTA titration will be sufficient. Information on EDTA is readily available; it is toxic only if ingested in large amounts. The LD_{50} (rat, oral) is 2000 mg per kg bodyweight.

(The revised classification shows that GHBA is in fact slightly **less** hazardous that EDTA)

ii) obtain further information which will enable a decision to be made on whether or not the reagent can be safely used. This type of task will often require the services of an occupational hygienist.

One of the common approaches used by toxicologists in this situation will be that of analogy, that is finding compounds with similar structures for which toxicological data **is** available or of predicting possible metabolites. Consultation with two professional. occupational hygienists pointed to the following facts:

(i) GBHA will probably be metabolised to substituted aromatic amines;

(ii) Many aromatic amines are known carcinogens of the bladder. However industrial experience has pointed to the fact that lengthy exposures are needed to induce a tumour:

(iii) The time of use and hence of potential exposure is very short and the quantities are very small. Thus it is reasonable to conclude that the risk is insignificant since the method and controls chosen virtually remove the chance of either a skin contact or of inhalation of the material.

This is, clearly, quite a lengthy and complex procedure.

In the case of such an experiment being carried out in schools, the sensible approach would be to contact SSERC and we will do the searching for you.

APPENDIX 1

Table of Hazard Categories

*The Health and Safety at Work Act requires **all** hazards and risks to be removed or, where that is not possible, to be reduced as far as is reasonably practicable. So a risk assessment should cover all the hazards that fall into the areas below.*

Table of Hazard Categories

Micro-organisms*	The standard types of activities carried out in schools are described and information sufficient to produce a general risk assessment provided in : Topics in Safety [ASE 3rd Ed] Chapter 15, SSERC codes of practice 'Safety in Microbiology' and 'Materials of Living Origin'.
Chemicals & Materials covered by COSHH	**all, whose bottles carry the appropriate Hazard Statements referring to substances that are toxic harmful, corrosive, irritant or with long-term health hazards.**. This information is most readily gleaned from suppliers' catalogues or bottles or from the Hazardous Chemicals Database on the SSERC website
Chemicals & Materials covered by DSEAR	**all, whose bottles carry the appropriate Hazard Statements referring to substances that are explosive, flammable or oxidising.** Again, this information is most readily gleaned from suppliers' catalogues or bottles or from the Hazardous Chemicals Database on the SSERC website
Other chemicals	In a few cases more research may be needed by the prospective user or by his employer about potential hazards of a substance. Usually suppliers can provide the necessary information on their safety data sheets (SDS). Schools and colleges, who are experiencing difficulty, should contact SSERC for help.
Dusts	Dusts of any sort, whether physically generated , e.g. wood dust, naturally occurring, e.g. pollen grains, or substances supplied as fine powder should not be inhaled.. Some dusts will already have been classed as being toxic or irritant, etc. But a few will not, e.g. polyethene powder used for dip coating. Of particular concern are wood dusts, fine sand from casting or metal fume from welding operations.
Optical radiation	*This will largely, though not exclusively, be confined to physics projects.* Bright lights, lasers in particular, can be extremely harmful to the eyes. The same is true for ultraviolet lights. Information on optical radiation can be found in the Physics H&S section of the SSERC Website. http://www.sserc.org.uk/index.php/health-safety/health-a-safety-home136/optical-radiation-safe-use81 and in Topics in Safety (ASE) Topic 18

Electricity	*This too will largely, though not exclusively, be confined to physics projects.* Much practical work used electrical devices and these should all be PAT tested. Additional guidance on Electrical safety can be found in the Physics H&S section of the SSERC Website. http://www.sserc.org.uk/index.php/health-safety/health-a-safety-home136/other/3349-electrical-safety and in Topics in Safety (ASE) Topic 17
Radioactivity	*This will largely, be confined to physics projects.* Work with radioactive substances is largely confined to physics investigations. Guidance on Ionising Radiation can be found in the Physics H&S section of the SSERC Website http://www.sserc.org.uk/index.php/health-safety/health-a-safety-home136/radiological-protection91 and in Topics in Safety (ASE) Topic 19
Manual Handling	This will not commonly be relevant but in cases where heavy pieces of machinery are moved around (water baths for instance) the Manual Handling Regulations will come into play.
Other	While most hazards will have been covered by the sections above, there may be others, in the case of biology field work for instance.

* The risk of catching an infection from a fellow class member or employee is excluded. The regulations apply when a micro-organism is deliberately used or if an infection might be transmitted from a laboratory animal.

There can be a multiplying effect on the total risk to health if a flammable substance is in the same flask as a toxic substance. In the event of a fire or explosion caused by the flammable substance, the toxic substance which otherwise would have been safely contained in a flask, will now be widely scattered.

APPENDIX 2

Substances in EH40 (Workplace Exposure Levels), but not having Hazard Statements

Substances are listed in EH40 because one of the main routes for their entry into the body is via inhalation; the WELs represent levels below which airborne concentrations must be reduced. Thus an important control measure for these substances is that of controlling vapours or aerosols (dusts and mists) generated from them. See also the note under the section on dusts and aerosols.

dusts and aerosols

aluminium	graphite	plaster of Paris
aluminium oxide	gypsum	quartz
boron oxide	iron oxide	fume rouge
barium sulphate	limestone	silica, fused; crystobalite
calcium carbonate	silicon carbide	starch
calcium hydroxide	MMMF	talc
calcium silicate	magnesium oxide fume	titanium dioxide
carbon black	manganese fume	tungsten
cellulose	marble	zinc oxide fume
cotton	mica	chromium
oil mist, mineral	copper fume & dust	oil, paraffin fume
emery	PVC	

It is difficult to see how many of these might in practice be dispersed into the air of a laboratory, e.g. barium sulphate or magnesium oxide. Most metal salts are normally available in crystalline form and many are deliquescent. Normal laboratory procedures such as weighing out a few grams and making up a solution will generate little or no dust. Although oxides and carbonates are often fine powders, a little extra care will ensure that no dust is dispersed during handling. Likewise careful handling during the breaking down from bulk by technicians or teachers will prevent the formation of dust clouds.

Even processes such as the grinding of a small quantity of say marble in a laboratory mortar, or the sieving of starch or finely powdered sucrose will hardly cause a high dust level. However the sanding or cutting of wood or PVC, grinding, the welding and brazing of metals or the burning of zinc powder or magnesium could give rise to high levels of either dust or of metal fume.

APPENDIX 3

Gases or aerosols which may be formed as a by-product

The Hazard Statements EUH029, EUH031 or EUH032 draw attention to such possibilities caused by the action of water or acid on a substance. Most of the following selection are well known.

agent released	**from**	
sulphur dioxide hydrogen sulphide chlorine	sulphite sulphide chlorate(I)	} + dilute acid
acid aerosol	dil. acid	+ metal, e.g. preparation of zinc sulphate
sulphur dioxide	sulphide (ores)	if oxidised by roasting in air
hydrogen cyanide	cyanides thiocyanate hexacyanoferrates	} + strong acids or by thermal decomposition
phosphine	phosphorus	+ sodium hydroxide
phosphorus(V) oxide	phosphorus,	if burnt in air or if oxidised,e.g., by concentrated nitric acid.
hydrogen halide	metal halide	+ strong acid. (bromides & iodides also give off sulphur dioxide & bromine) and (sulphur dioxide, iodine & hydrogen sulphide) respectively
arsine	arsenic compounds	} + reducing agent in acid
stibine	antimony compounds	
carbon monoxide	several organic acids	by dehydration (concentrated Sulphuric acid) or by thermal decomposition
nitrogen dioxide	nitrates nitric acid	} + concentrated sulphuric acid or by thermal decomposition
	air	by sparking, welding
cyanogen	air	arcing across carbon electrodes
ozone	air	UV light
nickel carbonyl	nickel	+ carbon monoxide
bis-CME	methanal	+ hydrogen chloride (solutions or vapour)
phosgene (carbonyl chloride)	chlorinated hydrocarbons	+ aluminium being degreased or on burning PVC
hexane	paint-/varnishing	
toluene	paint-/varnishing	
nitrosamines	sec. amines	+ nitrites

APPENDIX 4

CARCINOGENS

The purpose of this appendix is to help with the identification of those substances which may be carcinogenic. Chapter 9 of Topics in Safety (ASE) contains excellent general advice on the use of carcinogens in schools and should be read in conjunction with this appendix.

When identified as being either carcinogens or mutagens, chemicals should, if at all possible, be substituted by alternatives of lower toxicity. If this proves impossible, greater than usual care should be taken to avoid exposure by both the inhalation route and by skin absorption where this possibility is indicated.

Considerable doubt has been thrown on the 'one-hit' theory (that a single exposure to a carcinogen will lead to cancer) because of the body's known ability to effect repairs and kill aberrant cells. However, repair mechanisms, if overloaded, will fail and a cancer will probably develop. It is still impossible to set a zero-risk level since the level of exposure affects only the probability of the illness, but not the severity. There are several cases where substances have been established as 'human carcinogens' as a result of heavy and lengthy industrial exposures, many of them in the earlier part of this century when occupational hygiene was poor or non-existent. Examples are the mining and refining of nickel and chromium ores or the use of their compounds in processes such as electroplating. The high risk of tumour induction caused by compounds of these metals comes mainly from inhalation of dust or aerosols. Normal, good laboratory practice ensures that the weighing out of a few grammes of a crystalline nickel or chromium salt or using dilute solutions of the same salts does not give rise to the formation of dusts or aerosols. On the other hand a process such as electrolysing a solution of a salt might become unacceptable if continued for a long time in an open lab.

The corollary is also true in that today's 'new' chemicals will not be much used until after an extensive regime of testing has been completed and the risks to health have been shown to be sufficiently low. Thus lengthy human exposure to these is unlikely and consequently it will be much more difficult to prove if recently synthesised substances are human carcinogens. Results of tests on animals and bacteria can be used as pointers but, for a variety of reasons, the conclusions from data obtained from these studies cannot be transferred with a high certainty to the human species.

Many mutagens, but by no means all, are carcinogens. Mutagenic substances should also be treated with respect, similar to that shown for carcinogens.

A substance can he recognised as a carcinogen if:

(i) it carries the H350 Hazard Statement 'may cause cancer' or H351 'suspected of causing cancer'.

(ii) the SDSs from suppliers state that the substance is a carcinogen;

(iii) it is categorised as a carcinogen in lists prepared by the IARC (International Agency for Research on Cancer) list or by the governments of other countries.

These three sources of information are briefly expanded upon and are followed by a selection made from the IARC and the ECHA lists. This widens the range and throws up the names of additional chemicals.

i) **Does the substance carry the H350/351 Hazard Statement**? The answer can be gleaned from the SSERC website. If the information is not there, it can be found in the current edition of EH40, from suppliers' catalogues or from the ECHA database

In the UK carcinogens are controlled in three main ways:

- the use, manufacture or importation of four substances is prohibited, namely, 2-naphthylamine, benzidine, 4-aminodiphenyl and 4-nitrodiphenyl or of their salts or any substance containing any of these compounds in a total concentration greater than 0. 1 percent
- a number of other chemicals which can be reliably shown to be carcinogenic may also be assigned an H351 Hazard Statement
- other chemicals suspected of being carcinogens, but which are not included in the H350/351 list may nevertheless be included in EH40. As with any other chemical included in EH40, their use will be subject to a risk assessment and the resulting appropriate control measures of keeping the aerial concentration well below the MELs.

(ii) **Material safety data sheets** may identify more substances as having carcinogenic potential than are labelled with the H350/351 Hazard Statement. Being named in one of these SDSs as a carcinogen or mutagen can be taken as a warning flag that the substance should be substituted by a less harmful one or, if that is impossible, handled with due care.

In the previous edition of this publication, correspondence with BDH (now part of Merck) produced the following :

"the phrases concerned with chronic toxicity in our data sheets are generally intended as guides for the industrial scale user of chemicals, rather than for the laboratory user.

in general, where laboratory scale operations are concerned, normal laboratory cleanliness and levels of protection will suffice, unless the data sheet specifically recommends further precautions." (our emphasis)

the phrases should not be used in isolation, but interpreted together with other information on the data sheet"

The writer of the reply stated that he "did not believe that BDH lists any materials likely to cause tumours after short exposure."

(iii) **IARC list**. This also includes only those substances for which reliable information and data exist. It is divided into three categories:

- those causally associated with cancer in humans (Group 1), i.e. **proven carcinogens**
- those probably carcinogenic to humans (Group 2A)
- those possibly carcinogenic to humans (Group 2B)

It also has Groups 3 (insufficient data) and 5 (not carcinogenic)

List of some common carcinogens

Chemical	IARC	GHS	Other Comments
4-aminobiphenyl	1	H350	
arsenic & compounds: mining, smelting	1	H350*	*UK refers only to arsenic(III) & (V) oxides.
asbestos (brake linings)	1	H350*	* as dust; individual minerals named
benzene	1	H350	
benzidine & salts	1	H350	
chlorinated ethers			
bischloromethyl ether (production)	1	H350	
monochloromethyl ether (tech. grade)	1	H350	
1 ,2—dichloromethoxyethane			
coal tars & pitches, soot	1	H350	IARC lists many polynuclear aromatics typical of combustion;
coal gasification, coke production	1	H350	
pyrolysis of organic materials	2a	H350	
mineral oils (untreated & mildly treated)	1	H350*	*ECHA lists various but only ‘Baseoil – unspecified’ – is carcinogenic
Cr(VI) compounds: pigments, mining refining, stainless steel welding	1	H350	
2-naphthylamine (dye manufacture)	1	H350	
nickel compounds (refining)	1	H350	
painting (occupational exposure)	1		
tobacco smoke	1		sidestream smoke (passive smoking) contains higher concentrations of’ N-nitroso compounds and aromatic armines than are present in inhaled smoke
vinyl chloride (chloroethene)	1	H350	
wood dust, beech & oak			
acrylonitrile	2a	H350	
benzidine based dyes	2a		*see Dyes & Stains sub—section
beryllium & compounds (refining)	2a	H350	

cadmium & compounds (smelting, electro plating, battery production)	2a	H350	*chloride, oxide, sulphate, sulphide & other compounds as inspirable dusts/aerosols
cobalt & compounds		H350	*as inspirable dusts/aerosols from metal or salts of low solubility
creosote	2a	H350	
alkyl esters			
diethyl sulphate	2a	H350	
dimethyl sulphate	2a	H350	
tris(2,3-dibrornopropyl) phosphate	2a	H350	use in flame retardants
trimethyl phosphates			
dimethyl hydrogenphosphite		H351*	* not harmonised
ethylene oxide (epoxyethane)	2a	H350	use as fumigant & sterilant
halogen cpds			
1,2-dibromoethane (resins solvent)	2a	H350	ethylene dibromide
dichloroethyne		H351	dichloroacetylene
4-chloro-2-methylphenylamine & salts	2a	H350	p-chloro-o-toluidine
l,3-dichloropropan-2-ol		H350	
dimethylcarbamoyl chloride	2a	H350	
epichlorohydrin (resin hardener)	2a	H350	l-chloro-2,3-epoxypropane
iodomethane		H351	
polychlorobiphenyls	2a	*	* not carcinogenic under GHS
methanal (preparing resins disinfectant, preservative)	2a	H351	formaldehyde
N-nitroso compounds	2a/b	H350	IARC list contains many cpds; ECHA lists several – all the harmonised ones are H350
diesel engine emissions	2a	H350	*contains N-nitrosodi(ethanolamine)
metal working fluids containing nitrite or nitrite forming compounds			*also substances which react with nitrite or with nitrogen dioxide to yield nitrosamines ECHA only lists isobutyl nitrite as a carcinogen. But nitrosamines are.
nitro cpds			
4-nitrobiphenyl		H350	
dinitromethylbenzenes		H350	dinitrotoluenes (mixture of isomers)

2-nitronaphthalene		H350	
propylene oxide (manufacture of resins, use as solvent)	2a	H350	
polycyclic aromatic hydrocarbons	*	H350	*see soots, etc (IARC) & pyrolysis products benzpyrenes, etc (UK)
silica crystalline	2a	H350*	foundry work, pottery, quarrying * not harmonised
styrene oxide	2a	H350	
vinyl bromide (production)	2a	H350	
ethanal (use as chemical intermediate or food additive)	2b	H351	Acetaldehyde
ethananamide (as chemical intermediate or solvent)	2b	H351	Acetamide
acrylamide (production of polyacrylarnides	2b	H350	
amines			
4-aminoazobenzene	2b	H350	
o-aminoazornethylbenzene	2b	H350	Dye production
aniline (phenylamine)		H351	
5chloro-2-methylphenyl amine		*	5-chloro-o-toluidine * Not harmonised. Most submissions do not have it as a carcinogen.
4,4 '-diaminodiphenylether	2b	H350	4,4 '-oxydianiline use in production of resins
2, 4-diaminomethoxybenzene	2b	H350	2,4—diaminoanisole
2, 4-diaminomethylbenzene	2b	H350	2, 4-diaminotoluene, 2,4-toluenediamine
4,4 '-diaminophenylmethane	2b	H350	4,4'—methylenedianiline
4-dimethylaminoazobenzene	2b	H351*	Methyl yellow * not harmonised but most entries have H351
2,4-dimethylaniline (2,4-xylidene)		*	2,4—dimethyiphenylamine * Not harmonised but no carcinogen submissions.
4,4 methylenebis(2-methylaniline) curing agent for epoxy resins	2b	H350	di(-4-amino-2-methylphenyl)methane
4,4' -methylenebis(NN-dimethylaniline)		*	di (4-NN-dimethylaminophenyl)methane Not harmonised but no carcinogen submissions.

2-methylphenylamine	2b	H350	o-toluidine
2,4, 5-trimethylphenylamine		H350	2, 4,5—trimethylaniline
4-nitro-2-aminomethylbenzene		*	4-nitro-2-aminotoluene, 4-nitro-o-toluidine, Not harmonised but no carcinogen submissions.
antimony(III) oxide	2b	H351	
bitumen (waterproofing, roofing, asphalting)	2b	*	Not mentioned in ECHA database
BHA (butylated hydroxyanisole)	2b	H350*	tert-butyl-4-methoxyphenol .Antioxidant, food preservative * not harmonised. Entries split between H350 and H351
bracken fern	2b		
(gamma)butyrolactone	2b	*	use as chemical intermediate Not harmonised but no carcinogen submissions.
carbon black extracts (used as pigment)	2b	H351*	Not harmonised. 75% of entries have no classification, rest are H351.
carpentry & joinery	2b		*see wood dust entries Al & B
(alpha)chloromethylbenzenes			
benzal chloride	2b	H351	(chloromethyl)benzene
benzyl chloride	2b	H350	(dichloromethyl)benzene
benzotrichloride	2b	H350	(trichloromethyl)benzene
halogenated compounds			
bromomethane		*	methyl bromide * Class 2 mutagen but not a carconogen
chloromethane		H351	methyl chloride
1, 2-dibromo-3-chloropropane	2b	H350	use as soil fumigant
1 ,4-dichlorobenzene	2b	H351	production of TDI
1 ,2-dichloroethane	2b	H350	ethylene dichloride
chlorophenols	2b		* Harmonised – not carcinogens
chlorophenoxy herbicides	2b		* Harmonised – not carcinogens
dichloromethane (methylene dichloride)	2b	H351	use as solvent, paint remover, aerosol
tetrachloromethane	2b	H351	carbon tetrachloride — use as solvent
1,1 ,2,2-tetrachloroethane			* Harmonised – not carcinogen
1,1 ,2-trichloroethane		H351	

tetrachloroethene	2b	H351	tetrachloroethylene
trichloroethene		H350	(trichloroethylene)
trichloromethane	2b	H351	(chloroform)
hexachlorobenzene (BHC)	2b	H350	
hexachlorocyclohexane	2b	H351*	* Mostly not harmonised but most entries for each form are H351. The only harmonised entry is the gamma form (lindane). This is not classed as a carcinogen.
dimethylformamide (as solvent)	2b	*	* Not a carcinogen in ECHA databse but a reproductive toxin.
1,4-dioxane	2b	H351	solvent, stabiliser in chlorinated solvents
ethyl acrylate	2b	*	* Harmonised – not carcinogen
hexamethylphosphoric acid triamide	2b	H350	hexamethylphosphoramide solvent for polymers, additives in resins
glycidyl ethers (epoxy propyl ethers)	2b	H350*	used in manufacture of epoxy resins * various different ones. More are H351 than H350
hydrazine & derivatives			
hydrazine & salts	2b	H350	
1 ,2-diethylhydrazine	2b	H351	production
1,1-dimethylhydrazine	2b	H350	
1,2-dimethylhydrazine	2b	H350	
phenylhydrazine		H350	
lead & inorganic compounds (in smelting, battery production)	2b	*	* Not harmonised but not carcinogens apart from lead chromate (H350)
nitro compounds			
5-nitroacenapthene	2b	H350	a dye intermediate
2-nitro-4-aminophenol			4-amino-2-nitrophenol * Not harmonised but not carcinogens
2-nitropropane	2b	H350	solvent & chemical intermediate
1-nitronaphthalene		H351*	* Not harmonised. 75% of submissions say non-carcinogenic, the rest H351.
dinitrobenzenes (all isomers)		*	* Harmonised – not carcinogen
dinitronaphthalenes (all isomers)		*	* Not harmonised but mutagens, not carcinogens
Mineral wool	2b	H351	
Man made mineral fibres	2b	H350	Ceramic fibre *(for diameters < 1μm)

phenylethene (styrene)	2b	*	* Harmonised – not carcinogen
potassium bromate(V)	2b	H350	Still used as a conditioner in flour in the USA though not in Europe.
propanolide (beta-propiolactone	2b	H350	
1,3-propanesultone	2b	H350	
safrole & dihydrosafrole*	2b	H350	* dihydrosafrole is not harmonised and there is no carcinogen submission.
TDI (toluene-2,6-di-isocyanate)	2b	H351	
thio compounds			
ethylenethiourea	2b	*	* Harmonised – not carcinogen (Reproductive toxin)
methylthiouracil	2b	*	* Not harmonised. 1 entry out of 30 gives H350
thioacetamide	2b	H350	
thiourea (thiocarbamate)	2b	H351	
4,4'-dithiodianiline	2b	*	* Not harmonised and there is no carcinogen submission.
urethane (ethyl carbamate)	2b	H350	
wood dust other than oak or beech	2b*		*as occupational carpentry
dyes & stains			
Disperse Blue 1	2a	H350	
Oil Orange SS	2b	H351	
Ponceau MX	2b		
Ponceau 3R	2b	H351	
Trypan blue	2b	H350*	* Not harmonised

There are several hundreds of dyes and it is not convenient to list them all. Furthermore the toxicology of many dyes is not fully investigated.

In general azo dyes synthesised from:

- double diazotised benzidines

- diazotised benzidine derivatives such as 3,3 -dimethylbenzidine (o-tolidine), 3,3 -dimethoxybenzidine (dianisidine) and from 3,3 -dichlorobenzidine

-aminoazobenzenes, aininonaphthalenes and certain aminobenzenes.

will be carcinogenic.

The carcinogenicity and the mutagenicity of particular azo dyes as indicated in animal experiments and in 'in vitro' tests have been attributed to the amines formed by the metabolic breakdown of the dyes. One of the transformation steps on azo dyes is the reductive cleavage of the azo link (—N=N—) to yield two amine fragments, either of which may be a carcinogenic agent.

If one of the likely reduction products is an amine mentioned above or listed in any of the above three categories, then it should certainly not be synthesised in schools.

There is good evidence that the presence of one or more sulphonic acid groups in the molecule increases the water solubility and greatly reduces the carcinogenic potency of most dyestuffs, although this is by no means universally true. Therefore it is generally better to choose water soluble dyes either as candidates for synthesis or use in the form of indicators or reagents. In solid form many dyes are quite powdery, but the risk of dust inhalation is over once the dye is dissolved. Thereafter care should be taken to avoid skin contact. For this reason it may be prudent to purchase certain dyes or reagents as solutions ready for use.

Certain dyes based on triphenylmethane and anthraquinone are carcinogenic.

Information on other particular dyes from other sources

Auramine G	proven animal carcinogen
Auramine 0	proven animal carcinogen
Azoblack	proven animal carcinogen
Bismarck brown V	suspect carcinogen
Chryoisidine R	proven animal carcinogen
Chrysoidine V	suspect carcinogen
Fast Blue B	suspect carcinogen
Fast Garnet GBC	suspect carcinogen
Fast Red	suspect carcinogen
Fast red TR	suspect carcinogen
Fuchsin (acid)	suspect carcinogen
Fuchsin (basic)	suspect carcinogen
Fuchsin RAL	suspect carcinogen
Janus Green	suspect carcinogen
Pararosaniline	proven animal carcinogen
Sudan (IV)	proven animal carcinogen
Rhodamine 6G	proven animal carcinogen
Rhodamine B	proven animal carcinogen

More information becomes available with time and SDSs for dyes and stains should be sought from suppliers at the time.

APPENDIX 5

SENSITISERS AND ALLERGENIC SUBSTANCES

Where possible it is worth avoiding contact with irritants and sensitisers either by substitution of the offending substance or by improved control and containment.

In general corrosives, solvents and detergents which can remove fats destroy the tissue of the skin, leaving it more vulnerable to attack by other chemicals. The results may be varying degrees of irritation and possibly dermatitis of the area contacted. Frequent immersion in water will accelerate the process. Preventing contact with the irritants usually effects a rapid cure.

Skin contact with certain chemicals may result in sensitisation. If the offending chemical penetrates the skin and forms a complex with a protein molecule, the body's immune system perceives the latter as a foreign protein and is stimulated to produce the particular antibody. A subsequent exposure to very small amounts, perhaps even only to micrograms, of the same chemical can provoke a severe response which is not necessarily confined to the new exposed area. The symptoms will often appear similar to those of contact dermatitis. The speed of onset and the severity of the attack will vary greatly for different persons.

In the respiratory tract hypersensitivities may appear as rhinitis, allergic extrinsic alveolitis or as asthma. Respiratory sensitisation usually results from direct exposure to the allergen by inhalation. In some cases a sensitiser taken up systemically by another route will target on the lungs. Many of the allergenic substances are proteins, carbohydrates or lipids coming from a wide variety of sources, e.g. cereals, insect scales or pollen. Others are inorganic or organic chemicals of relatively low molecular weight.

All persons will not be affected by all of the substances in the lists below, nor with the same degree of severity. There is no way of knowing in advance which persons are likely to become sensitised. A consideration of the very different responses provoked by grass pollen in sufferers and non-sufferers of hay-fever makes the point clearly.

The lists below should be used as a warning flags to draw attention to the possibilities. With time and experience other substances might be revealed as being sensitisers. Look out for the GHS Hazard Statements H334 'May cause allergy or asthma symptoms or breathing difficulties if inhaled'.) and H317 'May cause an allergic skin reaction'. Suppliers SDSs should also reveal if a substance is a sensitiser.

EH40[7] adds the "sen" notation to substances which are well authenticated as sensitisers. They are:

Azodicarbonamide

Chromium (VI) compounds (as Cr)

Cobalt and Cobalt compounds (as Co)

Flour dust

Glutaraldehyde

[7] EH40 2011 edition

Halogeno-platinum compounds

Hardwood dust

Isocyanates (methyl isocyanate)

Maleic anhydride

Nickel and its inorganic compounds

Phthalic anhydride

Piperazine

Piperazine dihydrochloride

Rosin-based solder flux fume

Softwood dust

Subtilisins

Trimellitic anhydride

Several of the following substances might well be used in schools and have been reported as being sensitisers. The simple precautions of avoiding both skin contact or breathing fumes will for most persons provide satisfactory protection.

Those substances which are marked with an * may also be respiratory sensitisers.

Skin allergens and irritants
acrylates
*amines, aliphatic & alicyclic
*amines, aromatic & derivatives
*benzenediamines (phenylene diamines), esp. the 1,4-isomer
benzene- 1,4-diol (hydroquinone)
chromic acid
*chromates, sodium, potassium or ammonium
cobalt and salts
chlorates(I)
chlorinated hydrocarbon solvents
chlorinated & nitrated benzenes
*epoxy compounds, e.g., glycidal compounds (uncured GRP coatings) epichlorohydrin
glutaraldehyde
mercury & compounds
mercury arcs, pumps
methanal & derivatives
methylethylketone oxime (butanoneoxime)
*nickel - oxides & salts

dinitrophenols & derivatives
paraffin (kerosene)
persulphates, sodium, potassium & ammonium
phenolic disinfectants
phenyihydrazines
white spirits
Known respiratory Sensitisers
diamines, tetramines, pentamines
platinum halides
chloroplatinates
aminoethylethanolamine (aluminium soldering)
colophony (soldering)
TDI and other diisocyanates
polyurethanes -paints & foams
hardening agents based on phthalic anhydride, trimellitic acid, triethylene tetramine (Araldite hardener), maleic anhydride
piperazine
reactive dyes
diazonium salts
Those from organic sources
animal fur & dander
antibiotic dusts
insect scales
lycopodium
rennet
proteolytic enzymes
fun gal spores
grain dusts — barley, wheat,
maize & flour
dusts
and cocoa dust
oil bean dust
Other miscellaneous contact sensitisers
celery
cement dust
coal tars
detergents, cationic

dyestuffs, especially azo & anthraquinone types
epoxyresins, (dust from incompletely cured samples)
photographic developers
lubricants & cooling fluids
cutting fluids
narcissus, lupins, tulips
*plant products, e.g., gums
*wood oils and dusts, e.g. western red cedar

Some persons have an enhanced response to several of the irritant gases and fumes frequently generated in the lab, e.g. hydrogen chloride, chlorine, sulphur dioxide, ammonia, nitrogen dioxide. Their exposure to these gases may bring on bouts of asthma.

APPENDIX 6

CALCULATION OF THE LEVELS OF CONTAMINANTS IN THE GENERAL ATMOSPHERE OF THE WORKROOM OR LABORATORY

In order to assess the hazard posed by airborne contaminants, you should list:

- ***the likely points where each contaminant can 'escape'.*** Experienced laboratory and workshop operators will have no difficulty in instinctively pinpointing such sources.
- ***the likely routes by which a particular substance enters the body***
- ***any toxicological information of interest***, eg. Values for LDLo, LD_{50}, target organ. whether toxic effects are acute or chronic and, if possible, some estimate of the degree of toxicity and whether the effects are reversible or irreversible. Information of this type is sometimes patchy.
- ***the WEL and the reference period*** (8 hours or 15 minutes). If referenced over 15 minutes this indicates that the substance is toxic in an acute sense and more care should be taken.
- ***the boiling point or some other index of volatility***.
- ***any index of flammability***. eg, flash point or of a particular incompatible combination which might be formed.
- ***first aid measures***. It is most unlikely that chemicals will be ingested as it is reasonable to assume that no one will deliberately eat or drink laboratory or workshop chemicals and that no mouth-pipetting is allowed. Nevertheless it is worthwhile including the first aid measures for all possible routes of absorption.

If you tie in the above observations with your assessment of the risk of exposure you obtain, you can then decide if there is a significant risk to the health of the persons handling the substances or of those working nearby and, if so, what measures you can take to reduce it.

Sometimes the simple estimation of the hazard of a volatile substance may be too crude. A finer assessment can often be made by direct calculation. If an estimate of the rate of release of a contaminant gas or vapour can be made, simple arithmetic will give in advance the concentration of that pollutant in the room.

If this figure is one tenth or less of the value of the Workplace Exposure Limit (LTEL or STEL) the process can be carried out in an open room, if not, a fume cupboard is required. Figures need only be approximate and can be rounded up or down.

The sense of smell should be taken as a useful warning that WELs are being approached or, in some cases, exceeded but **it is not a reliable guide**. Whilst several substances can be smelled at concentrations below the WELs, others are only detected at levels above them. Furthermore several vapours paralyse the olfactory nerve and hence the absence of a smell cannot always be taken to mean that the concentration levels are adequately low. Irritation of the eyes, skin or throat almost certainly indicates that the concentration of pollutants is too high.

The Occupational Health and Environmental Safety Division of 3M produced a publication to aid selection of the right respirator. (2010 Respirator Selection Guide[8]). The guide, contains a table listing many chemicals and there is a column in the table which gives the odour threshold.

As far as inhalation is concerned, a control measure or precaution taken to reduce the exposure is legally deemed to be adequate if:

- for substances assigned an WEL if the concentration is below that WEL. (it is permissible to exceed the WEL provided that remedial action is being taken).

- for substances assigned an WEL the concentration is reduced, so far as is reasonably practicable, below that WEL, (getting the concentration just below the WEL is not necessarily meeting the legal requirements of COSHH. On the other hand an occasional excursion above the WEL is not necessarily indicative of a failure to maintain adequate control).

Workplace Exposure Limits are largely decided with industrial usage in mind and the concentration is usually averaged over an 8 hour period. Some chemicals also have listed a 15 minute time weighted average and this is closer to the typical length of a release of a gas or vapour in most school activities. Because this is defined as a weighted average, an exposure pattern of 200 ppm for 8 minutes followed by 2 minutes of zero exposure would result in a TWA level of 160 ppm. This exposure might or might not be acceptable, depending on the toxic nature of the chemical concerned. It might seem tempting to push this arithmetical logic further and suggest that 600 ppm of nitrogen dioxide breathed for 5 seconds or 3000 ppm for 1 second would be no more dangerous than breathing 5 ppm for 10 minutes. No doubt such extreme use of averaging would be considered a contravention of the Health and Safety at Work Act.

Release rates for many typical school practical activities are given in Table 2 at the end of this appendix.

[8] It can be downloaded here: http://www.lbl.gov/ehs/chsp/html/OdorThresholds-3MRespiratorSelectionGuide.pdf

Methods of calculation

In general terms, it is normal to use the simplest way provided that it is appropriate to the situation.

However, given the ubiquity of access to spreadsheets that was not the case at the time of the first edition, apparently complex calculations can be done as easily as simple ones.

Equation 3 is used in a spreadsheet for calculating release rates See page 63

Equations 1 and 2 below are special cases of equation 3. The three equations described below are followed by worked examples. Since the size of a room is constant and its ventilation rate reasonably so, the formulae can be simplified. This has been done assuming a room of volume 300 m^3 with 4 air changes per hour, but it is a simple matter to adapt calculations for smaller rooms.

Equation 1 - calculation of limiting concentration after long releases

$$\text{limiting concentration} = \frac{R \times 3600 \text{ ppm}}{nV}$$

where R = *rate of release* ($cm^3\ s^{-1}$)

V = *room volume* (m^3)

n = *no of air changes/hour*

= **3R ppm** for 300 m^3 room with 4 air changes per hour

If the calculated concentration is less than the safe reference level the process can be carried out indefinitely in the open lab. If on the other hand it comes out above the safe reference level, it will be necessary to use one of the two remaining formulae to see for how long the release can be safely made.

Equation 2 - sealed room approximation

$$C_t = \frac{R \times t}{V} \quad ppm$$

where V = *volume of room* (m^3)

R = *rate of release* ($cm^3\ s^{-1}$)

t = *duration of release (seconds)*

C_t = *concentration of vapour at time t in ppm*

Since real rooms have **some** ventilation this will always be an over estimate. The error is only 5 or 10 minutes (see Fig. 1) in any additional margin of safety.

Equation 3 - ventilated room

$$C_t = \frac{R \times 3600}{V \times n}(1-e^{-nt}) \ ppm$$

where V = *volume of room* (m^3)

n = *no of air changes/hour*

R = *rate of release* ($cm^3\ s^{-1}$)

C_t = *concentration of vapour (ppm)*

t = *time after start of release (hours)*

$= 3 \times R(1 - e^{-4t})$ for the 300 m^3 room with 4 air changes per hour.

For convenience, ready reckoners in the form of a table (Table 1) and a graph (Fig. 2) have been constructed from equation 3.

The relationship of the three calculations can be seen by examination of the graphs in Figure 1.

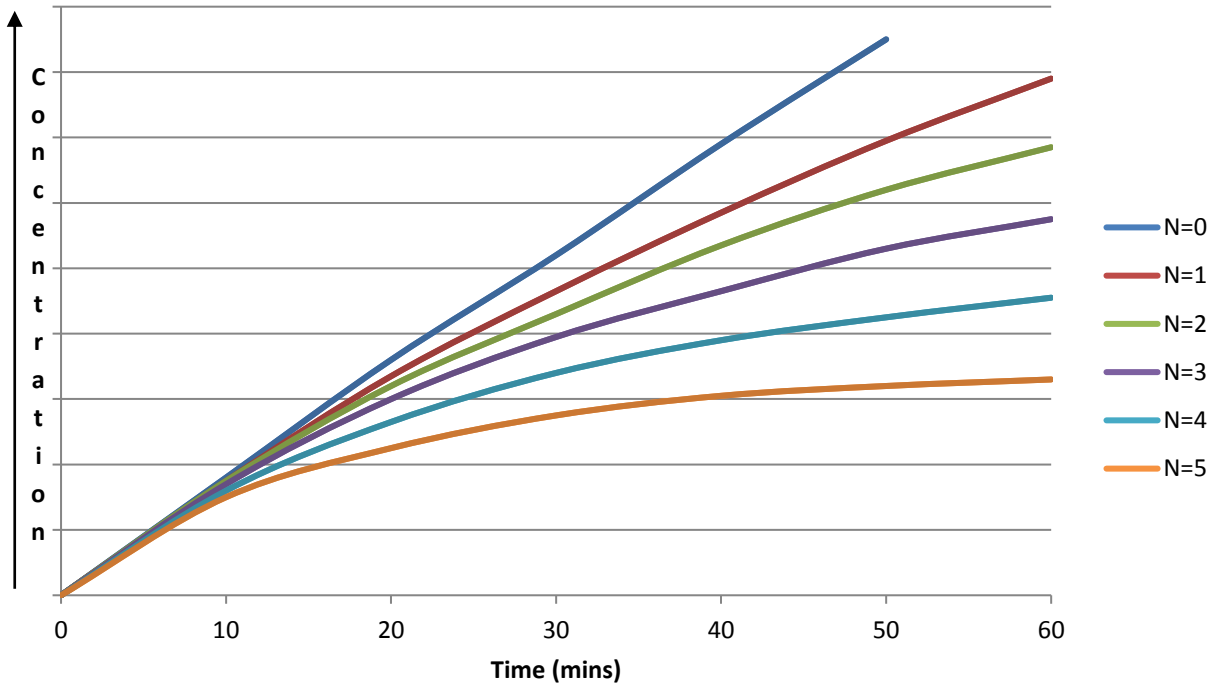


Figure 1: Concentration of pollutant against time for a release rate of 1 cm^3/s in a room of 300 m^3 with different numbers (n) of air changes per hour

The curves are all derived from equation 3. Notice that:

- C_t reaches the limiting value, equal to R/nV ppm, after a long interval
- the sealed room is a special case where n = 0.

Most rooms in older schools have up to 2 air changes per hour resulting from natural ventilation due to air leaks through the door and window seals and with occasional opening of the door. More

modern buildings, though, are less draughty, which is good but also will often have fewer windows that open and which will often only open to a small degree.

The rate of ventilation can be increased by leaving more windows open on a windy day, if this is possible with the design of your laboratory, or by forced ventilation.

SSERC and the ASE recommend that a school chemistry laboratory should be ventilated to a minimum of 5 room changes per hour. There is no need to have that level of ventilation on a permanent basis but it should certainly be possible to achieve 5 ach when required.

Time after start of release	**Concentration (ppm) produced by release rates of (cm^3 s^{-1})**					
	1	**2**	**3**	**5**	**10**	**20**
2 s	0.007	0.013	0.02	0.03	0.07	0.13
30 s	0.1	0.2	0.3	0.5	1.0	2.0
1 min	0.2	0.4	0.6	1.0	1.9	3.8
2 min	0.4	.07	1.1	1.9	3.7	7.5
3 min	0.5	1.1	1.6	2.7	5.4	10.9
5 min	0.9	1.7	2.6	4.2	8.5	17
10 min	1.5	2.9	4.4	7.3	14.6	29
15 min	1.9	3.8	5.7	9.5	19	38
20 min	2.2	4.4	6.6	11	22	44
30 min	2.6	5.2	7.8	13	27	52
50 min	2.9	5.8	8.7	14.5	29	58
90 min	3.0	6.0	9.0	15	30	60

Table 1 – Ready reckoner for the concentration of a contaminant for different rates of release in a room of 300 m^3 with 4 air changes per hour

Note that for any given time the concentration produced is directly proportional to the release rate. A scan across any horizontal row in the table will show this to be true. Thus provision of the concentrations at different times for the one release rate of 1 cm^3 s^{-1} would have been sufficient to permit estimates to be made for all calculations but the extra information has been added for convenience.

For times or for release rates intermediate between those in the table an adequate answer can be obtained by interpolation, but the graph in Fig.2 can be used with advantage here. Read off the concentration at any time from the curve for a release rate of 1 cm^3 s^{-1} and scale it up to the actual release rate.

Eg For a release rate of 7 ppm, after 30 minutes

From the graph, for 1 cm^3 s^{-1} you get 2.6 ppm

Multiply by 7 = 18.2 ppm

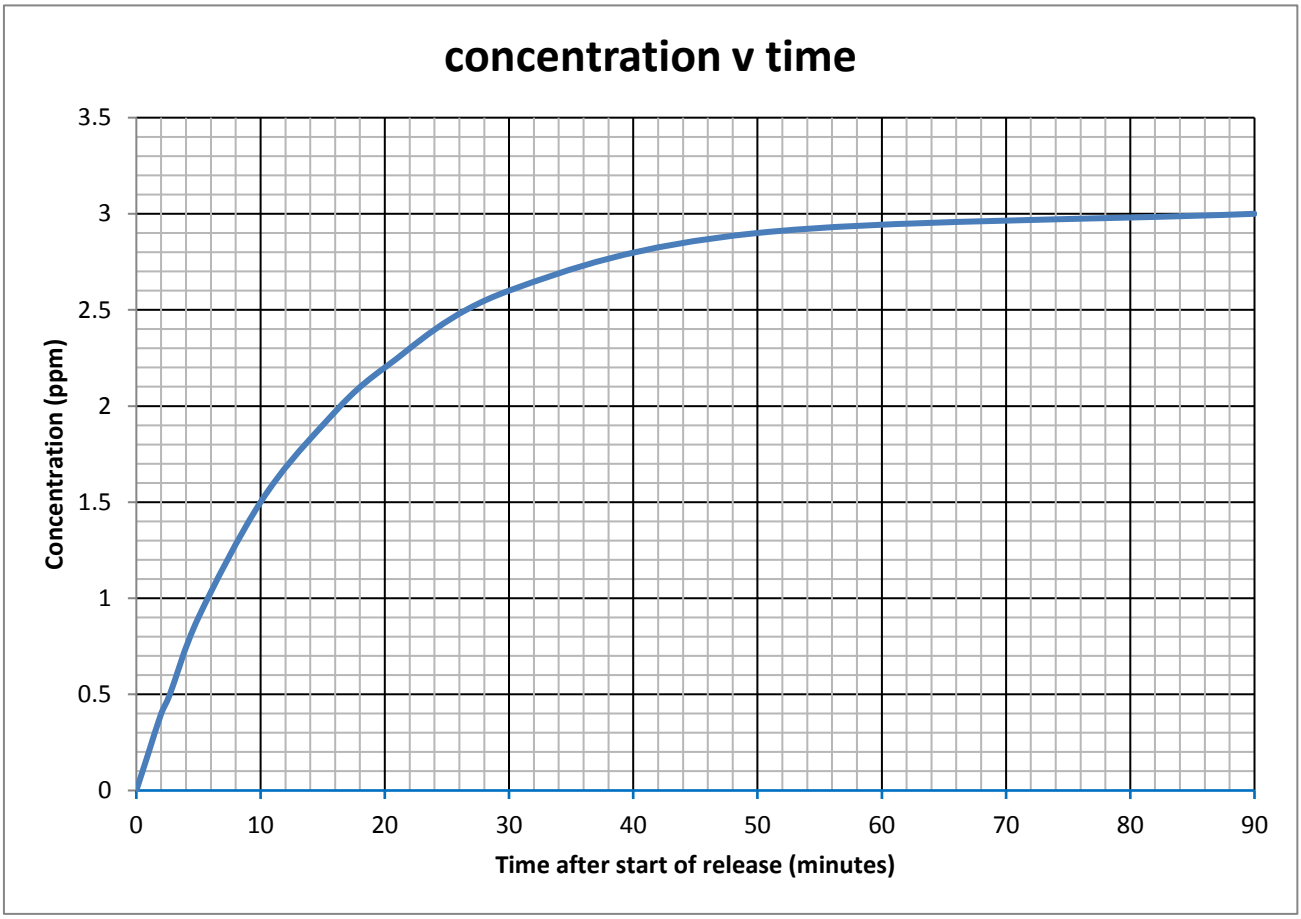


Fig.2 Graph of concentration v time for release rate of 1 cm^3 s^{-1} in a 300m^3 room with 4 ACH

Safety factor - K

When a gas or pollutant is released into a room the concentration will be locally higher in the neighbourhood of the source than if it were uniformly mixed throughout the room. To take account of this uneven distribution the calculated concentration should be compared not with the WEL but with a reference level equal to that limit divided by the safety factor, K.

Sax[9] defines values for K for several types of air movement and extraction systems

The nearer the source of pollution to the extract fan and the better engineered the inflow of make-up air, the lower is the value of K. The toxicity of the substance will also affect the value of K; a localised concentration of vapour is less tolerable for a highly toxic substance than for one of low toxicity. The values for K in a room with 'poor distribution', e.g. an open laboratory, are taken from 'Sax'.

[9] Dangerous properties of industrial materials. Sax & Irving

Toxicity		K
	TLV of> 10 min	
Low	>200 ppm	7
Moderate	< 200 ppm	8
High	< 50 ppm	11

Sax uses the magnitude of the TLV (threshold limiting value) to classify the levels of toxicity. For this purpose UK WELs can be used instead.

For most calculations a simple rule of thumb is to use 10 for K.

For very short lived releases of vapours of low toxicity, e.g., those lasting less than 2 minutes, it might seem reasonable to reduce the values of K. However K should never be less than 5.

Example 1 – What will be the atmospheric concentrations at 5, 10 and 40 minutes after 2 pupil pairs start to evaporate ethanol in the 300 m^3 laboratory with 4 ach?

Table 2 (on p60) informs us that the release rate for this process is 5 cm^3 s^{-1}

Total rate of release = (2 x 5) = 10 cm^3 s^{-1}

Scan down the column for the release rate of 10 cm^3s^{-1} in Table 1 and read off the answers of

5 minutes – concentration = 8.5 ppm

10 minutes – concentration = 14.6 ppm

40 minutes – concentration = 28 ppm

The reading for 40 mins is obtained by interpolation.

Precise answers are not needed and the other answers for 5 and 10 minutes could be rounded off to the nearest whole number.

Alternatively the graph (Fig.2) can be used by reading off the concentrations produced by a release of 1 cm^3s^{-1} and then scaling up the answer.

These would come out at (10 x 0.85), (10 x 1.45) and (10 x 2.8) ppm respectively. Note that the sealed room formula (equation 2) gives a reasonable answer for a five minute release, namely (10 x 5 x 60)/300 = 10 ppm, but that its answers of 20 and 40 ppm are too high for the other two times.

Example 2 – Can (i) phosphorus (III) chloride and (ii) butanone (methyl ethyl ketone) with a release rate of 5 cm^3 s^{-1} be handled in the open lab?

Consult EH40 and Table 2 to find out the WELs and the likely release rates for handling the two substances.

<u>phosphorus(III) chloride</u>

the limiting concentration. = 3R = 15 ppm and the reference level (divided by K) is 0.2/10 or 0.02 ppm

butanone

the limiting concentration. = 3R = 15 ppm and the reference level (divided by K) is 200/10 or 20 ppm

Clearly the phosphorus(III) chloride must be handled in a fume cupboard if the time of handling is other than very short.

It is readily seen that, as far as toxicity is concerned, butanone can be handled indefinitely on this particular scale and method. Flammability considerations might, of course, dictate otherwise.

Example 3 – can 10 pupil pairs carry out a test tube scale polymerisation of phenylethene which is reckoned to last 5 minutes? This will be in the open lab (300 m^3 with 4 ach)

as well as illustrating other aspects of calculations, this problem has something of an element of a trick question but all will be revealed later.

(i) a process where 2-methylcyclohexanone is released at a rate of 4 cm^3 s^{-1} ?

(ii) trichloroethene is handled with a release rate of 5 cm^3 s^{-1} ?

(iii) polymerisation of methyl 2-methylpropenoate?

(i) from EH40, the WEL of 2-methylcyclohexanone = 50 ppm (8 hr TWA) or 75 ppm (15 m) and carries a 'skin notation'

=> safe reference level (divided by K) = 5 ppm

Limiting concentration = 3R = 12 ppm. This exceeds the reference level, so the process cannot be carried on for long periods in the open lab.

Using Table 1 interpolate between release rates of 3 and 5 cm^3s^{-1} . This give an answer of between 5 and 10 minutes.

Another way of tackling this is to use the fact mentioned earlier that at any instant the concentration of pollutant is proportional to the rate of release. Either read off from the graph in Fig.2 the time required for the release rate of 1 cm^3s^{-1} to produce a concentration of 1/4 of 5 ppm (about 8 minutes) or use the ready reckoner in Table 1 to see how long a release at the rate of 2 cm^3 s^{-1} takes to reach a concentration of 1/2 of 5 ppm.

The results indicate that a fume cupboard is required if the process is going to take longer than 10 minutes. Also, because this compound has a 'skin' notation, extra precautions should be taken to ensure that the skin is protected.

(ii) WEL of trichloroethene = 100 ppm (8 hr TWA) or 150 ppm (15 m)

=> safe reference level (divided by K) = 10 ppm

Table 1 indicates a release rate of 5 cm^3 s^{-1} will cause this to be reached in about 15 minutes. However since the substance has been assigned an MEL, it would be prudent to handle this substance in a fume cupboard unless the time of release is very brief.

EH40 also indicates that the substance is readily absorbed by the skin and therefore suitable gloves will have to be worn. Consult Appendix 10 for initial guidance on the choice of suitable gloves. Nitrile or PVC should do.

(iii) WEL of methyl 2-methylpropenoate = 100 (8 hr) and 125 (15 m)

=> safe reference level (divided by K) = 10 ppm

Table 2 indicates the release rate for the experiment is about 10 cm^3 s^{-1} . Limiting concentration = 3R = 30 ppm which exceeds the reference level. Table 1 indicates the reference level is reached in less than 10 minutes, which is not long enough for the polymerisation to be completed.

Another point here is that most acrylates are known to be skin sensitisers (see Appendix 4). Simple extra precautions are needed.

Other sizes of room

Some processes will be carried out in smaller rooms, e.g. prep rooms or Sixth Year labs. For all three formulae it is just a matter of inverse proportion; in a 100 m^3 room the concentration reached at any instant will be three times that in the 300 m^3 lab at the same time. When the calculation is reversed to that of estimating for how long a given release can be made, the sealed room formula and the ventilated room behave differently. The former predicts the same concentration will be produced in one third of the time, whilst the latter shows this will be reached in much less than one third of the time.

Other factors

Regardless of the results of calculating or of experimentally determining aerial concentrations, fume cupboards should be used where a volatile substance:

- **is a carcinogen**; substitutes will presumably have first been sought before proceeding;

- **has an STEL** as opposed to an WEL; see comments above in examples involving phenylethene and trichloroethane;

- **is a recognised respiratory sensitiser**. SDS from suppliers should contain this information. Refer also to Appendix 5.

Release rates for some typical school experiments

Table 2 (on p 60) contains the release rates for several substances using the scale and methods usually found in school experiments. A list of this size cannot possibly cover all the processes which will arise in the course of project work. It may be necessary to estimate release rates for these processes. This will often be a fairly easy task and may be achieved by either simple calculation or by practical measurements.

Example of a calculation

The estimation of the release rate of bromine formed by the electrolysis of a molten bromide by the passage of a current of 2 A.

$Br^- \rightarrow \frac{1}{2} Br_2 + e^-$

1 mole of Bromine needs 2 moles of electrons.

1 mole of electrons = 1 Farad (96,500 coulombs)

t = time (mins)

i = current (A)

z = number of electrons needed per molecule of gas

v = volume of gas released (cm^3)

Vol of 1 mole of gas = 24,000 cm^3

So to work out the release of Bromine, z = 2 (2 electrons needed per molecule of Br_2)

$$v = \frac{(i \times t \times 60) \times 24{,}000}{(96{,}500 \times z)}$$

Consider doing this for 5 minutes

$$v = \frac{(2 \times 5 \times 60) \times 24{,}000}{(96{,}500 \times 2)}$$

$= 74.61\ cm^3$

Negligible quantities of bromine will dissolve in the melt.

Division of this by the estimated length of time for completion of most of the reaction gives the release rate averaged over the period.

$0.249\ cm^3\ s^{-1}$

This gives a maximum or worst case.

Another example of this might be the thermal decomposition of metal nitrates.

Details of how to set up an excel spreadsheet to carry out these calculations can be found on p 63.

Practical measurements could involve carrying out the process for a short trial period and either weighing the reaction vessel before and after gas evolution or by use of a gas syringe. In many cases it may be advisable to carry out the trial in a fume cupboard. Division of this quantity by the probable length of time for which the gas is evolved will give the release rate in mg s^{-1} or directly in $cm^3\ s^{-1}$. Mass can be converted to volume by assuming the molar volume of gases at room temperature to be 24,000 cm^3

Another useful conversion is that of changing mg s^{-1} to ppm. Multiply by the factor

$$\frac{\mathbf{24}}{\mathbf{molecular\ mass}}$$

A good way of remembering which way round to put the factors is that concentration expressed in ppm is, for virtually all gases, a smaller number. The reverse is only true for light gases like

ammonia or methane. Should you forget, a quick glance at a random sample in EH40 will soon remind you.

Tabl;e 2: Release rates for typical classroom activities

Much of the data for the release rates in Table 2 (below) is used with permission of CLEAPSS. Many of the releases are normally short lived with typical duration time (t).

R = Release rate (cm^3 / second)

T = time of release (seconds)

(Ct) is the concentration built up in time (t) in a 300 m3 with 4 air changes per hour.

* data was found by experiment

data was found by calculation.

Chemicals released and experiment	R	T	C_t	Control limit (ppm)	
	Cm^3s^{-1}	min	ppm	(8h)	(10 min)
Ammonia				25	35
by boiling .880 ammonia	90*	5	77		
evaporation	50*	10	45		
Bromine				0.1	0.3
Reaction with other metals	1.25*	2	0.9		
pouring	1.8*	10s	0.06		
electrolysis of melts with 10A current	1.25	10	1.9		
Chlorine				1	3
prep 75 g $KMnO_4$ + conc HC1	12*	10	18		
Chromates				0.05 mg/m^3	
heating 20 g of ammonium dichromate(VI) (volcano experiment')	0.3 mg/m^3	10	0.06 mg/m^3		
Ethanal				100	150
preparation	10	5	8.5		
pouring (reactions)	40*	10s	1.3		
Ethanol				1000	
Evaporating	5	10	7.3		
Pouring	1.8	10s	0.06		
heating to boiling point	100	5	85		
Ethoxyethane				400	500
evaporation	20*	5	7		
separating funnel extraction	1.3*	2	0.5		
Ethanoyl chloride				5 [10]	
Preparation	8*	10	12		
pouring (use in organic preps)	20	10s	0.03		
ethylamine				10	
pouring	1	10s	0.03		
Ethyl ethanoates (& analogues)				400	
pouring (reactions)	20	10s	0.1		

[10] No OEL but use that for HCl

Hydrogen chloride					5
Preparation	10	10	15		
test tube preparation	0.4	2	0.3		
reaction of $AlC1_3$, PCl_3, etc with water (as in disposal)	15*	12	25		
iodine					0.1
heating 0.02 g in test tube	.03	1	0.006		
reaction with aluminium	4	2	1.5		
reaction with metals	<0.1	2	0.04		
test tube preparation	0.1	2	0.04		
Lead fume				0. 1mg/m^3	
electrolysis of $PbBr_2$ (fume)	0.03*	10	0.05 mg/m^3		
reduction of lead oxides	0.04 mg/m^3	1	0.008 mg/m^3		
methanal				2	
pouring	0.3	10s	0.003		
preparation of urea resins	0.4	5	0.5		
handling biological specimens	0.7*	20	1.5		
methylbenzene				100	150 sk
pouring	4	10s	0.13		
making HC1 solution	4	5	3.6		
Methyl -2-methylpropenoate				100	125
Polymerisation	10	20	22		
Pouring	2.5	10s	0.08		
depolymerisation	2	2	0.7		
naphthalene				10	15
cooling curve	0.18*	5	0.1		
Nitric acid				2	4
Preparation	1.3	10	2		
test tube scale prepn.	1	1	0.2		
Nitrogen dioxide				3	5
prepn. (Cu + HNQ3)	7*	3	3.5		
test tube scale heating of nitrates	1.7*	1	0.		
phenylethene				100	250 MEL
boiling tube scale polymerisation	1.8*	50	5		
Phosphorus(III) chloride				0.2	0.5
pouring	5*	10s	0.17		
Paper chromatography - drying of paper of area 500 cm^2 soaked in:					
Butan-1-ol	2*	10	2.9	50	50
Ethoxyethane	33	1	7	400	500
Phenol	0.4*	20	1	5	10
Pyridine	5*	15	9.5	5	10
Pet ether (40-60)	4	2	1.4	100[11]	

[11] Use OEL for hexane

t is in minutes except where otherwise stated

C is in ppm except for solid or fume where it is in mg m^{-3}

Sk means that the substance is strongly absorbed through the skin as well as via the inhalation route. Thus the skin must be fully protected if the WEL is to be meaningful.

WELs are Long Term (8 hour) Exposure Limits unless marked STEL.

*WELs of mixtures have to be calculated as described in EH40. Alternatively use the lowest WEL in the mixture, namely hexane. Often a supplier will have recommended an WEL for the mixture in the SDS.

Use of Spreadsheets

Equation 3 can be entered into a spreadsheet as follows:

Quantitity	Unit	Value
Volume of room	m3	300
time (t)	mins	5
Ventilation (rch)		2
release rate	cm3/s	0.2487
concentration of vapour	ppm	**=(D8*3600*E6)/(D5*D7)**

This can be extended for calculations from electrolysis reactions.

Quantitity	Unit	Value
current (i)	Amps	1
time (t)	minutes	5
electrons needed per molecule (z)		2
No of coulombs per mol		96500
Vol of 1 mole of gas	cm3	24000
volume of gas released	cm3	**=((D16*D17*60)/(D19*D18))*D20**
Release rate	cm3/s	**=D21/(D17*60)**

Quantitity	Unit	Value
Volume of room	m3	300
time (t)	mins	5
Ventilation (rch)		2
release rate	cm3/s	=D22
concentration of vapour	ppm	**=(D29*3600*E27)/(D26*D28)**

APPENDIX 7

USEFUL SOURCES OP INFORMATION FOR PREPARATION OF ASSESSMENTS

Depending on how an Education Authority (or other employer) delegates responsibilities and tasks, some of the following sources may be transferred from shelves in schools to those of an adviser and area chief technician or in the other direction:

(a) for schools*

Hazardous Chemical Database, (SSERC) members only

http://www.sserc.org.uk/index.php/chemistry-health-a-safety138/hazardous-chemicals276

Topics in Safety, 3rd Edition (ASE), price £15 (members) £30 (non-members). (*This publication is currently being revised and rather than produce a complete new edition, ASE is publishing the chapters independently as pdf files available from the website*).

Safeguards in the School Laboratory 11th Edition (ASE), price £15 (members) £21 (non-members).

'**Safety in Microbiology**: A Code of Practice for Scottish Schools and Colleges' (SSERC)

'**Materials of Living Origin – Educational Uses**: A Code of Practice for Scottish Schools and Colleges' (SSERC)

Both can be downloaded here:

http://www.sserc.org.uk/index.php/biology-2

Hazard Data sheets or SDS from several suppliers. These are currently available online from several suppliers, particularly Sigma Aldrich and Fisher

(b) - for science advisers, safety officers, chief technicians to hold, or have access to, in addition to the above

Control of substances hazardous to health - approved code of practice, (HSE), £12.50 from HSE. Or a free pdf download from here

https://books.hse.gov.uk/hse/public/saleproduct.jsf;jsessionid=D392C478980EF2AEFF380011751CD84D.plukweb1?catalogueCode=9780717629817

EH40/-- Occupational Exposure Limits, (HSE), current version available from HSE £15.00 or a free pdf download from here:

http://www.hse.gov.uk/pubns/books/eh40.htm.

ECHA database – a database of all the EU classifications for chemicals under GHS.

http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database

Merck Index, an encyclopaedia of chemicals and drugs, (Merck & Co Ltd), £99.99 from the RSC shop. This contains abbreviated data on over 10,000 chemicals and biological substances.

There is a limited free search facility but full access to the website comes with buying the print version.

Poisonous plants in Britain and their effects on Animals and Man, (Ministry of Agriculture, Fisheries and Food, Reference Book 161), ISBN 0 11 242529 1, £12.95

(Out of print but still readily available)

The following pocket versions of larger works may be found very useful:

Rapid guide to hazardous chemicals in the workplace Richard Lewis 4th Ed 2000 price £45.00

CDC NIOSH pocket guide to chemical hazards. Available for sale, (£19.00) to download as a CD-ROM or an online facility here:

http://www.cdc.gov/niosh/npg/

(b) to consult

Sax's Dangerous properties of industrial materials, Richard. J. Lewis Sr, Wiley, £463 This specialist book gives toxicity data, hazard ratings and other information on approximately 20,000 chemicals.

EH Guidance Notes on particular chemicals; an up to date list of those available can be found in the current EH40.

Documentation of the Threshold Limit Values for Physical Agents, 7th Ed' by American Conference of Industrial Hygienists ACGIH ($99.00)

Toxnet – A search tool of the US National Library of Medicine. There is a single search box that allows you to search a dozen or so databases on toxicology, hazardous chemicals, environmental health, and toxic releases. (http://toxnet.nlm.nih.gov/index.html)

This list does not claim to be exhaustive. There are very likely to be other suitable sources of useful information.

** For England and Wales, CLEAPSS produces Hazcards. Teachers or technicians moving to Scotland may be more familiar with these but the information contained therein is duplicated in the relevant pages on the SSERC Hazardous Chemicals Database.*

APPENDIX 8

SOURCES OF INFORMATION ON METHODS OF MONITORING AND ON EQUIPMENT

While it is fairly straightforward to carry out spot measurements for concentration of airborne contaminants, any longer term monitoring, is more complex. It is unlikely to be required in a school but if so, expert help should be sought.

Some processes do not already have a general assessment to lean on nor is the necessary information available to enable estimates of atmospheric concentrations to be calculated as shown in Appendix 6. The only way to deal with these cases may be to carry out atmospheric measurements of the concentration of the pollutant, e.g. dust, methanal (formaldehyde).

(a) information on methods of monitoring

Details of analytical methods can be obtained from several sources, but the value of those listed in either "The Methods for the Determination of Hazardous Substances" (MDHS) series published by the HSE (http://www.hse.gov.uk/pubns/mdhs/#a3253) or in the 'NIOSH manual of analytical methods' (http://www.cdc.gov/niosh/docs/2003-154/) is that these methods are tried and tested.

Some determinations use fairly simple colorimetric methods but others will require the use of sophisticated analytical techniques such as AAS, GC, MS, XRF or HPLC to determine the quantities of pollutants captured on a filter or charcoal adsorbent. In some regions the Regional Analyst is already performing some of these tasks for the education sector. Otherwise it might be necessary to employ a consultant. One national body which can provide a complete service is the Institute of Occupational Medicine. (http://www.iom-world.org/)

(b) Information on equipment used in monitoring

(i) Personal air dust sampling kit - for total dust this consists of a portable pump (2 litres/min) fitted with a rechargeable battery, tubing and filter holder, rotameter to adjust the pump speed and a means of calibrating the rotameter. The latter is an air flow meter with a float in a tapered tube. For measuring respirable dust a cyclone separator or MRE elutriator is also needed. Typical prices for a basic kit from two of the many manufacturers are in the region of £400. The extra costs are £50 for the separator and £70 for the rotameter. This will require to be calibrated using the familiar soap bubble flowmeter. Commercial versions such as the 'Mini-Buck' cost around £900. Some of the pumps can easily be converted to run at low flow rates, which will give them an additional use of measuring organic vapours adsorbed onto charcoal or Tenax tubes. A balance with sufficient sensitivity to give a reproducibility of ÷/-0.03 mg is recommended; these may well be available in local FE colleges or universities. Some manufacturers or suppliers are:

SKC Ltd – (http://www.skcltd.com) - 11 Sunrise Park, Higher Shaftesbury Road, Blandford Forum, Dorset DT11 8ST

Sabre Gas Detection (http://www.sabreh2s.com/) Sabre Safety Ltd., Sabre House, Cupar Trading Estate, Cupar, Fife, Scotland, KY15 4SX (They don't do dust monitoring)

(ii) **Gas and vapour detection tubes and pumps** - these operate a little like the first generation of breathalyser tubes: A known volume of air is drawn through the tubes by a special, calibrated pump. The tube contains reagents that change colour when they react with the gas being detected. The tube has a scale printed on it and the concentration can be read off directly according to the length of the stain. The hand-operated pumps cost between roughly £200 and £300

The detector tubes, which can only be used once, are sold in packs of 10, typically at around £30 - £60 per pack, depending on the make and the particular gas being sampled.

The tubes are designed to work at a particular flow rate, which is provided by the pump from the same manufacturer. These methods can be inaccurate by as much as 25% and are subject to interference from other gases. Nevertheless the method is certainly good enough for an initial survey and perhaps even for a final one too. No special operator skills are needed. Some suppliers are:

The three major manufacturers are Gastec, Draeger and Kitigawa.

Some suppliers are:

A1-Cbiss: 12 Finns Industrial Park, Mill Lane, Crondall, Farnham, GU10 5RX

Tel: 01252 850165

http://www.a1-cbiss.com/gas-detection-analysis/gastec-gas-detector-tubes-pumps

Draeger Ltd: Ullswater Close, Blyth Riverside Business Park, Blyth, Northumberland, NE24 4RG

Tel: 01670 352 891

http://www.draeger.com/sites/en_uk/Pages/Industry/ProductSelector.aspx?navID=1419

MSA [Britain] Ltd: Lochard House, Linnet Way, Strathclyde Business Park, Bellshill ML4 3RA

Tel; 01698 57 33 57

http://gb.msasafety.com/Portable-Gas-Detection/c/114?N=10139&Ne=10180&isLanding=true

Scotsafe: *(Distributor of Kitigawa gas testing tubes)* Scotsafe Testing Ltd, 17 Woodlands Drive, Kirkhill Industrial Estate, Dyce, Aberdeen, AB21 0GW

Tel: 01224 771200

http://www.scotsafe.co.uk/contact.asp

There are also automated systems, some of which use the same tubes described above. The prices of these range from around £800 to £1600

Others which have mini detectors mounted on chips (CMS). These are more expensive, costing from around £1,800 upwards.

All of the systems mentioned above give ‘snapshot’ samples of the air quality. In the vast majority of cases, this approach will be sufficient. If there is a suspicion that there is a release of harmful vapours during a particular process, the apparatus can be set up and run and the air quality

measured at various points. (technicians' workstations or adjacent to fume cupboards for instance).

If there is a more general concern about exposure in the workplace, a different approach will be needed.

(iii) **personal sampling of gases and vapours** - this involves the person being monitored wearing either personal electronic monitor. (Depending on the gas being monitored, these cost roughly from $350 to £600 but will work for quite a few years) a NIOSH adsorbent tube or a passive adsorbent 'badge' on the lapel; the pollutants are removed later by either thermal desorption or by solvent elution and analysed by GC, HPLC or by spectroscopy. Unless you have access to the Regional Analyst's services it will be better to hire the services of a consultant. Typical prices from one national body, the Institute of Occupational Medicine are £20 for the first element or component in the mixture plus £10 for each additional component subject to a minimum charge of £120. Thus the minimum charge might cover up to six different sample measurements if only one pollutant is concerned. Analysis of dusts and metal fume is slightly cheaper. The Institute is based in four centres in the UK:

IOM, **IOM Edinburgh,** Research Avenue North, Riccarton, Edinburgh, EH14 4AP.
Tel: +44 (0)131 449 8000,
Email: info@iom-world.org

OM Chesterfield, Tapton Park Innovation Centre, Birmingham Road, Tapton, Chesterfield, S41 0TZ
Tel: +44 (0)1246 383110
Email: info@iom-world.org

IOM Stafford, Brookside Business Park, Cold Meece, Stone Staffordshire, ST15 0RZ.
Tel: + 44 (0)1785 333200
Email: info@iom-world.org

OM London Research House Business Centre, Fraser Road, Perivale, Middlesex. UB6 7AQ
Tel: + 44 (0)203 668 0000
Email: info@iom-world.org

APPENDIX 9

RESISTANCE OF GLOVES TO CHEMICALS

Personal protective equipment such as gloves should be one of the last control measures to be used in attempting to reduce the risk of skin contamination. If an artefact was to be immersed in a bath of etchant or degreasing solvent it would be preferable to use an engineering means such as holding it in a cradle or cage. Gloves are not designed for continuous immersion in solvents. Having said that, there are many situations in laboratories where, in addition to good technique, gloves will be the means of protecting the hands. Examples are weighing out solids and making up solutions, decanting from bulk or shaking a separating funnel containing a solvent.

In order to get adequate protection gloves must be matched to the chemicals being used. To make a choice you need to:

- examine the process and decide how likely will be the contact of chemicals on the gloves. Is it a case of possibly just a few drips or is a larger splash likely?
- list the chemicals and solvents. Find out how readily they are absorbed through the skin and how toxic they are once absorbed by consulting suppliers SDSs, Hazardous Chemicals Database, etc.
- look at the glove manufacturer's chemical resistance chart and choose a glove type to which he has assigned a high to medium resistance. Some manufacturers supply technical details such as the breakthrough time or permeation rates. Other manufacturers provide a four or five point scale ranging from Not Recommended' at one end to 'Excellent' at the other. These gradings are a composite or compromise of the above two properties and the rate of degradation of the glove material by the solvent.
- decide on the likely abrasion to which the gloves will be subjected. Heavier gloves are obviously more hard wearing, but their use may well pose a greater risk to health if the reduced manual dexterity causes equipment to be dropped. Most laboratory operations do require the extra dexterity, do not have a high probability of spillage and light or medium weight gloves are satisfactory. For preparation from bulk and for some other tasks the use of heavier gloves is advisable. In addition thicker gloves of the same material will have a longer breakthrough time.
- consider the size; oversized gloves are a menace.

It looks at first sight that several different types of glove will be necessary to be able to cope with the whole range of materials likely to found in schools. There is a glove material which will stand nearly all chemicals, but at £30 a pair, 'Viton' might not seem a starter. The alternative approach is to use one type of glove material for most operations, e.g. PVC and replace it with nitrile for the small number of cases where it would fail to provide adequate protection.

The table below is a reduced version of a glove resistance chart available from James North & Sons and reproduced with their permission. The chart itemises individual members of each chemical 'family'. Since most of the members show very similar behaviour towards a particular glove material, they are dealt with here as families. PVC gloves are cheap, afford reasonable dexterity and are chosen here as the standard glove for most operations. The performance rating,

which is a composite of a number of factors is given on a four point scale, - 1 (excellent),2, 3 & NR (Not Recommended) and an average figure for the family is given here. In the few instances where a particular member of a family behaves very differently it is specially listed.

Chemical family	Type of gloves			Comments
	PVC	Nitrile	Natural Rubber	
Inorganic acids	1	2	2	
Nitric acid	2	NR	NR	
Aqua regia	3	3	NR	
Organic acids	1	1	1	Includes phenol
Saturated salt solutions	1	1	1	Includes Iron III chloride
Alkalis	1	1	1	
Aliphatic hydrocarbons	2/ NR	1	3/ NR	
Iso-octane	NR	1	NR	
pentane	NR	1	3	
Aromatic hydrocarbons	2/3	1/2	NR	
styrene	NR	2	NR	
Ethers	3	2	3	
Halogenated hydrocarbons	3	2/3	3	
trichloroethane	3	3	NR	
Amines	1	1/2	2/3	
Amide solvents	NR	NR	2	e.g.dimethylformamide
Alkanols	1/2	1	½	
Alkanones	3	2	3	
Alkanals	1	1	3	
Esters	3	2	3	
Miscellaneous				
Diesel fuel	3	2	NR	
Paint removers	3	2	3	
Photographic solutions	2	1	2	
White spirit	3	2	3	

Formulations and proportions of the same elastomer will vary between different makes of the same type of glove, so do not expect all gloves of the same polymer to have identical properties. **However the above table can be used as a quick guide. Clearly glove materials should not be used for applications labelled 'NR'. Those assigned a '3' could be used in situations where**

only slight splashing is likely. Nitrile would seem to be a reasonably good alternative in most of those cases where PVC is unsatisfactory.

A more comprehensive guide can be found on the SSERC website[12].

Once a glove has been immersed in a solvent, diffusion will continue through the glove material for some time afterwards. Because of this disposable gloves have an obvious advantage but against that must be placed the poorer performance of smaller thicknesses. When handling substances known to be particularly toxic by skin absorption it may be advisable to replace gloves after each use unless they are particularly thick. Gloves should be washed before removal.

Some system of marking such as colour coding is a good aid to identification of glove types.

[12] http://www.sserc.org.uk/index.php/chemistry-health-a-safety138/background-info208/protective-equipment/1745-personal-protective-equipment-gloves

Appendix 10

EYE PROTECTION

The Law

The main responsibility to provide a healthy and safe working environment lies with the employer; employees must, however, cooperate with the system the employer sets up, following any instructions and guidance provided. They must also exercise a commonsense care for the health and safety of themselves and others. The section also explains that, while an employer must delegate health & safety functions to different employees, this does not necessarily imply delegation of responsibility.

The specific PPE Regulations do not cover pupils but the *Health & Safety at Work Act* requires the employer to take care of them and the PPE Regulations will be considered to provide appropriate guidance.

PPE must be adequate and appropriate for its intended use; an assessment of risks must be made before any is provided. For example, eye protection must be suitable for the activity it is to be used for and fit properly. It must be properly maintained.

What does this mean?

You should wear at least basic safety spectacles (to British/European Standard BS EN 166, previously BS2092) whenever there is the possibility of any damage to the eye, either by impact, contact with micro-organisms or when chemicals with a hazard classification are handled.

They should also be worn when using some chemicals that are sufficiently dilute that they do not need to carry a hazard warning (eg, iodine solution, limewater etc) but are nevertheless irritating to the eyes.

Special requirements

Impact

There are various activities that may lead to the need to protect the eyes from impact. If the activity is likely to lead to the potential for high energy impact, then it is not appropriate to rely solely on eye protection; engineering controls should be put in place to make the whole process less hazardous.

Chemicals

Goggles which protect the eyes against chemical droplets/splashes (to BS EN 166 3) or face shields marked BS EN 166 3 should be worn when handling:

- all chemicals classified as CORROSIVE (eg, bromine, alkali solutions at more than 0.5 M concentration, concentrated acids, solids such as calcium oxide and phenol);
- all chemicals classified as TOXIC.

The point is that there is not a requirement for any specific equipment but a requirement that there be a certain level of protection from risk for the pupils.

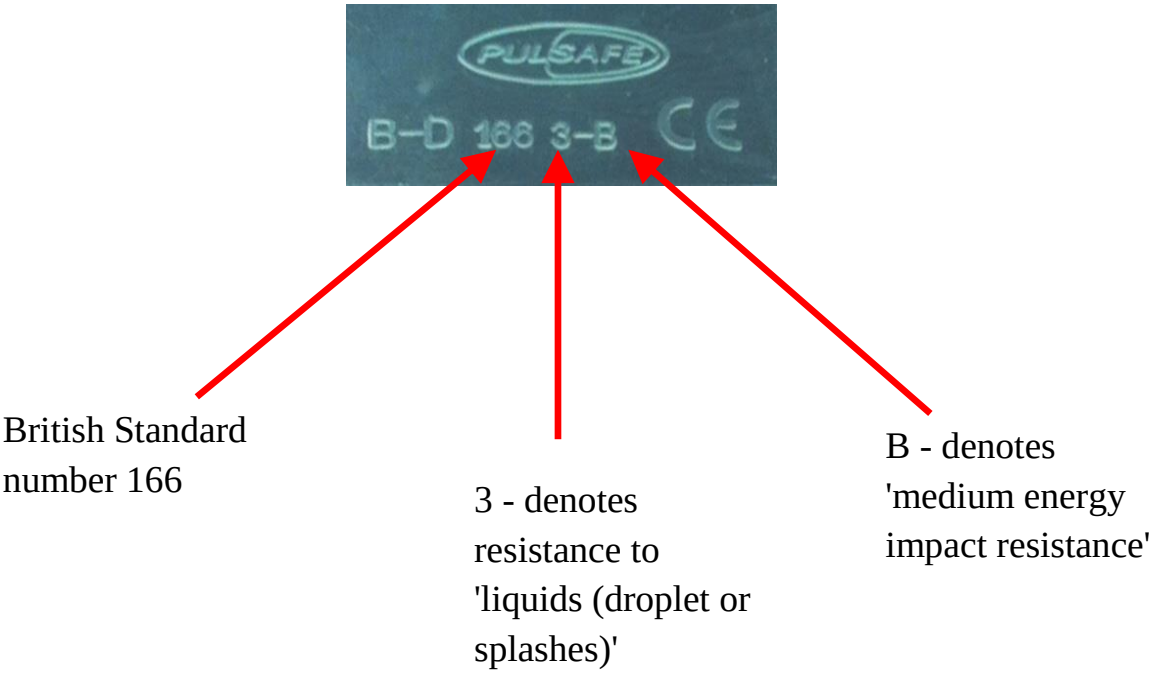
What to look for

Somewhere on the goggles/glasses, you will find a code that tells you about the specifications of the equipment.

What you are looking for first of all is the number 166 – this is the BS EN number.

After that, there are different letters and numbers that can mean a variety of different things. (See the diagram on the following page).

The key one is a 3 – which means they are splash resistant and thus can be used when dealing with toxic or corrosive liquids.



Fields of use	**Mechanical strength**	**Other markings**
3 - resistant to liquid droplets (goggles, indirect & direct vent), or liquid splashes (faceshields, but not mesh)	S - increased robustness ≤ 12 m/s (Safety specs - marked on lenses only)	K - resistant to surface damage by fine particles (marked on lenses)
4 - resistant to coarse dust particles >5μm (goggles, indirect & direct vent)	F - high speed particles, low energy impact ≤ 45 m/s (Shields, goggles & safety specs)	N - resistant to fogging (marked on lenses)
5 - resistant to gas and fine smoke/ dust particles < 5 μm (goggles, unvented)	B - high speed particles, medium energy impact ≤ 120 m/s (goggles and faceshields only)	G - resistant to radiant heat (marked on frame)
9 - resistant to molten metals and hot solids (goggles and faceshields)	A - high speed particles, high energy impact (faceshields only – only rarely required even in industry)	H – Designed to fit small head. (marked on frame)

In Summary:

1) Eye **protection** (and safety specs are quite adequate in this case) must be worn whenever a practical activity is being carried out that might pose some risk to the eye when:
    a. Using some chemicals – as stated above (not corrosive or toxic or eye irritants)
    b. Carrying out experiments such as bending glass or stretching springs/elastic bands where a sudden snap might propel something towards the eye.
2) However – for work using chemicals as described above (corrosive or toxic) then spectacles are not adequate and an incident could, in a worst case scenario, lead to prosecution under H&S legislation – though this would be unlikely.
3) By far the easiest option, therefore, is to have goggles all round with the thinking that it is better to be over-protected for a few activities than under-protected for any.
4) If it is deemed by the management that this is not a financially viable option and they are refusing to pay extra for goggles then there are a couple of options:
    a. Do not carry out any practical work involving any corrosive or toxic chemicals. Not a very good idea as come inspection time HMIe would be distinctly unimpressed.

b. Have safety specs for all pupils and a class set or two of goggles that can be moved around to the different groups depending on when they were needed. This would need quite a bit of organization
    i. Well in advance to make sure that there are not more classes scheduled to use corrosive/toxic chemicals at a time than there are sets of goggles
    ii. Day to day to make sure that the goggles are moved around as and when they should be – this can be dealt with by having an entry on the lesson requisition form specifying specs or goggles.

Appendix 11

GHS Classification

Introduction

At the time of going to press, the switch over to the GHS/CLP classification system was still going on.

Timescale for Labelling

Substances – pure chemicals such as copper sulphate or ethanol. Has to be classified under GHS from Dec 2010 (though stock already labelled was allowed to be sold until June 2013)

Mixtures – any mixture, including solutions. These should be classified under GHS from June 2015 (though stock already labelled will be allowed to be sold until June 2017)

In practice, chemical suppliers used by schools have already switched over for all their stock rather than have the complexity of running two parallel systems.

Many products used in technology departments, however, are still, at the time of writing, classified under CHIP.

Timescale for Submission

The process is as follows.

1. The manufacturer or importer carried out testing on the product and submits their assessment to the European Chemicals Agency (ECHA).

2. ECHA consider all the submissions and then come up with a harmonised classification which will then apply to that chemical throughout the EU.

The timetable for registration is:

By November 2010

- all carcinogens, mutagens and reproductive toxins produced/imported in quantities greater than 1Tonne per annum.
- all classified as harmful to the aquatic environment produced/imported in quantities greater than 100 Tonnes per annum.
- all other chemicals produced/imported in quantities greater than 1000 Tonnes per annum.

By May 2013,

- all other chemicals produced/imported in quantities greater than 100 Tonnes per annum.

By May 2018

- all other chemicals produced/imported in quantities greater than 1 Tonne per annum.

Harmonisation

At the end of 2013, ECHA had completed harmonised classifications for 5% of the chemicals submission: although this number does include a large number of substances in use in school science laboratories. Where a chemical does not have a 'harmonised' classification, frequently there are inconsistencies between suppliers about the hazards of, and hence the hazard statements to be used for, that chemical.

As a result it is quite possible that a substance used in project work will have a different classification depending on where it is purchased from.

The table below shows the hazard statements given in catalogues by a number of suppliers for a chemical which schools commonly use, copper(II) chloride-2-water. The lack of consistency between suppliers emphasises that assignment of hazard statements is not a precise science. Different suppliers obtain their chemicals from different manufacturers and these are tested separately for toxicity, corrosivity and other hazardous properties. The different tests tend to give different results, either because of differing methodologies or just inherent variation in procedures involving living organisms.

For instance, in the case of copper(II) chloride-2-water, the WHO on its Environmental Health Criteria[13] gives an LD50 of 140 mg kg^{-1} (oral, rat).

Sigma, however, gives a figure of 336 mg/kg, Merck 584 mg kg^{-1}, Fisher 584 and 140 mg kg^{-1} and Scichem's data sheet says no data were available.

Because of this lack of consistency, it is entirely reasonable for health and safety experts involved in science education to use their judgement in balancing the apparent hazards against the educational advantages of using the chemical. Copper(II) chloride is often used in solution when teaching electrolysis because of the nature of the products at each electrode. It has been used for many years with no evidence of any problems and there is no reason to stop using it.

Supplier	Hazard statements for copper II chloride – 2-water									
	H290	H301	H302	H312	H315	H318	H319	H335	H400	H410
Breckland			✓		✓		✓	✓	✓	
Fisher	✓	✓			✓		✓	✓	✓	
Merck			✓		✓		✓		✓	✓
Philip Harris			✓		✓		✓	✓	✓	✓
Scichem		✓			✓		✓			✓
Sigma	✓		✓	✓	✓	✓			✓	✓
Timstar			✓		✓		✓	✓	✓	

Table 3: Variation in hazard statements between suppliers.

[13] Environmental Health Criteria 200: Copper (1998) by the International Programme on Chemical Safety (IPCS)

Key to Table above

H290	*May be corrosive to metals*
H301	*Toxic if swallowed*
H302	*Harmful if swallowed*
H312	*Harmful in contact with skin*
H315	*Causes skin irritation*
H318	*Causes serious eye damage*
H319	*Causes serious eye irritation*
H335	*May cause respiratory irritation*
H400	*Very toxic to aquatic life*
H410	*Very toxic to aquatic life with long lasting effects*

Appendix 12

The effect of concentration on classification

This is easier to determine for some hazards than others.

For explosive, flammable and oxidising substances, for instance, there is no easy way to determine the effect.

It is clear for example that pure ethanol is highly flammable and a gin and tonic is not. The same holds true for all flammables. There is, however, no simple way of calculating the change in classification.

The same is true for oxidisers and explosives.

There are some categories, though for which general rules can be applied.

1. Corrosivity

Many corrosive substances will have specific limits that can be found on the SSERC website. For those that do not, the following general rules can be applied.

Initial classification	**Cat 1**	**Cat 2**	**Not classified**
Cat 1 (A/B/C)	≥ 5%	≥ 1% but < 5%	< 1%
Cat 1 but pH is ≤ 2 or ≥ 11.5*	≥ 1%		
Cat 2		≥ 10%	< 10%

* There is an anomaly here in that it appears that a corrosive of high or low pH never reaches the stage at which it becomes less hazardous. Homeopaths may be pleased but the rest of us should use our common sense.

2. Acute toxicity

This classification varies depending on the avenue by which the toxic agent has its effects.

Initial classification	**Cat 1**	**Cat 2**	**Cat 3**	**Cat 4**	**Not classified**
Oral					
Cat 1	≥ 10%	< 10% but ≥ 1%	< 1% but ≥ 0.2%	< 0.2% but ≥ 0.03%	< 0.03%
Cat 2	- - -	≥ 10%	< 10% but ≥ 1.7%	< 1.7% but ≥ 0.25%	< 0.25%
Cat 3	- - -	- - -	≥ 33.3%	< 33.3% but ≥ 5%	< 5%
Cat 4	- - -	- - -	- - -	≥ 25%	< 25%
Dermal					
Cat 1	≥ 10%	< 10% but ≥ 2.5%	< 2.5% but ≥ 0.5%	< 0.5% but ≥ 0.3%	< 0.3%
Cat 2	- - -	≥ 25%	< 25% but ≥ 5%	< 5% but ≥ 2.5%	< 2.5%
Cat 3	- - -	- - -	≥ 30%	< 30% but ≥ 15%	< 15%
Cat 4	- - -	- - -	- - -	≥ 55%	< 55%

Respiratory (gas)					
Cat 1	100%	< 100% but ≥ 10%	< 10% but ≥ 1.4%	< 1.4% but ≥ 0.2%	< 0.2%
Cat 2	- - -	100%	> 100% but ≥ 14.3%	< 14.3% but ≥ 2.2%	< 2.2%
Cat 3	- - -	- - -	100%	> 100% but ≥ 15.6%	< 15.6%
Cat 4	- - -	- - -	- - -	100%	< 100%
Respiratory (vapour)					
Cat 1	≥ 10%	< 10% but ≥ 2.5%	< 2.5% but ≥ 0.5%	< 0.5% but ≥ 0.3%	< 0.3%
Cat 2	- - -	≥ 25%	< 25% but ≥ 5%	< 5% but ≥ 2.5%	< 2.5%
Cat 3	- - -	- - -	≥ 30%	< 30% but ≥ 15%	< 15%
Cat 4	- - -	- - -	- - -	≥ 55%	< 55%
Respiratory (dust)					
Cat 1	≥ 10%	< 10% but ≥ 1%	< 1% but ≥ 0.5%	< 0.5% but ≥ 0.1%	< 0.1%
Cat 2	- - -	≥ 10%	< 10% but ≥ 5%	< 5% but ≥ 1%	< 1%
Cat 3	- - -	- - -	≥ 50%	< 50% but ≥ 10%	< 10%
Cat 4	- - -	- - -	- - -	≥ 30%	< 30%

3. Other hazards

Initial classification	**Cat 1**	**Cat 2**	**Not classified**
Skin sensitiser Cat 1	≥ 1%	- - -	< 1%
Respiratory sensitiser Cat 1	≥ 1%	- - -	< 1%
Aspiration toxin Cat 1	≥ 1%	- - -	< 1%
Carcinogen Cat 1a/b	≥ 0.1%	- - -	< 0.1%
Carcinogen Cat 2	- - -	≥ 1%	< 1%
Mutagen Cat 1a/b	≥ 0.1%	- - -	< 0.1%
Mutagen Cat 2	- - -	≥ 1%	< 1%
Reproductive toxin Cat 1a/b	≥ 0.3%	- - -	< 0.3%
Reproductive toxin Cat 2	- - -	≥ 3%	< 3%
Specific target organ toxin Cat 1	≥ 10%	< 10% but ≥ 1%	< 1%
Specific target organ toxin Cat 2	- - -	≥ 10%	< 10%
Specific target organ toxin Cat 3	- - -	≥ 20%	< 20%

4. Environmental toxicity

These are a bit more complex in that many environmental toxins have what are called M factors assigned to them. If there is no M factor given, as long as you have access to toxicological data it is possible to calculate one from the table below.

L(E)C50 value	**Multiplying factor (M)**
$0.1 < L(E)C50 \leq 1$	1
$0.01 < L(E)C50 \leq 0.1$	10
$0.001 < L(E)C50 \leq 0.01$	100
$0.0001 < L(E)C50 \leq 0.001$	1 000
$0.00001 < L(E)C50 \leq 0.0001$	10 000
(continue in factor 10 intervals)	

To find the effect, multiply the concentration by the M factor and then compare it to the table below. For instance, a 1% solution of a substance where M=10 gives an effective 'concentration' of 10%

Initial classification	**Cat 1**	**Cat 2**	**Cat 3**	**Cat 4**	**Not classified**
Cat 1	≥ 25%	< 25% but ≥ 2.5%	< 2.5% but ≥ 0.25%	< 0.25% but ≥ 0.025%	< 0.025%
Cat 2	- - -	≥ 25%	< 25% but ≥ 2.5%	< 2.5% but ≥ 0.25%	< 0.25%
Cat 3	- - -	- - -	≥ 25%	< 25% but ≥ 2.5%	< 2.5%
Cat 4	- - -	- - -	- - -	≥ 25%	< 25%

If you have a mixture with substances of different classification, things are a little more complex still.

For example, if you have a mixture of categories 1 & 2, then, for it to be rated Cat 2 the sum of % of the cat 2 substance (x the M factor) and 10 x the % of the Cat 1 substance (x its M factor) must be less than or equal to 25%. To be rated Cat 3, the sum of 10 x the % of the cat 2 substance(x the M factor) and 100 x the % of the Cat 1 substance (x its M factor) must be less than or equal to 25%. And so on.

Appendix 13

SEMI-QUANTITATIVE METHOD

Introduction

In the main, there is no need for a quantitative approach to risk assessment. Especially considering the great number of assumptions that have to be made in order to assign numbers to hazards and risks, which makes the values obtained fairly arbitrary.

We realise, however, that a numerical approach, as used in the previous edition of this handbook, is preferred by some people so we have retained it.

This method is an adaptation of the one in the previous (1991) edition which in turn was an adaptation of an RSC method. It is a semi-quantitative approach in which ratings or scores are allotted to the scale of operation. how easily the substance is disseminated about a room and to the type of containment used. These are fed into an equation or read into an array which then indicates a measure of the risk.

Although the device is a simplified scheme and some steps may appear somewhat arbitrary, it will be useful in reaching a decision on many processes.

1. Fill in the three ratings labelled (a), (b) and (c) for each substance by reference to Table 1 and multiply them together to give the Exposure Potential. This is a measure of the ease with which the substance will escape, disseminate itself and thereby reach someone's body.
2. Assign a Hazard Category to each substance by using Table 2
3. Refer to the array in Table 3 to obtain the Risk Index which gives an indication of the risk to health on a three point scale. This also tells you whether or not a fume cupboard is necessary and if the process should be even started at all.

It is important to consider by-products as well as any intended main product, even though they are often produced only in small amounts. In most cases the low ratings for quantity, physical characteristics and for the method of containment will ensure that the risk to health is low. An example of this is the small amount of 1,2-dihromoethane produced in aqueous solution when a few drops of bromine water are added to a test tube of ethene, which is then stoppered and shaken.

If the product concerned is commonly used in schools and colleges, you will be able to find information about the hazards, as well as information on its handling etc from the SSERC Hazardous Chemicals Database.

If the product is not listed by SSERC but has been purchased, then manufacturers Safety Data Sheets (SDS) will be available. In this case, though, it is worthwhile contacting SSERC for advice.

If the product is more unusual and not produced commercially,(a by-product of a process for instance) then no SDS will be available. You will have to turn to a variety of original sources. Contact SSERC and they will be happy to assist.

The information on a SDS will be useful in deciding on what constitutes an adequate control measure. The main categories are mentioned below.

Physical data - boiling and melting points, vapour pressure and other indices of volatility, density relative to air (if a gas or vapour) and solubility in water will help you to estimate the ease with which a substance will disseminate itself. The most appropriate methods of containment can be chosen accordingly.

Health hazard information - this should include the most likely routes of absorption and the effects of overexposure in both the short and long term. Take special note where substances are known sensitisers or where they exert irreversible effects on health, e.g. are carcinogenic, mutagenic or teratogenic.

If '*target organs'* are known this may be helpful in deciding if two different substances in the same cocktail will act independently or if both attack the same organ, thereby producing an additive effect. EH40/2011 Has a useful section on mixed exposures and how substances can interact.

Fire and Explosion data - which gives flash points, autoignition temperatures, explosive limits

First Aid and the **Spillage** measures may indicate things like having a solution of thiosulphate present to treat any bromine which accidentally lands on the skin. Also usually included are other types of data which, though not strictly of use for your risk assessments, will be needed to handle the substances safely and meet the general requirements of the Health and Safety at Work Act, such as information on Reactivity and Chemical Incompatibility.

Calculating the Risk Index

Step 1 - Use the table below to Estimate the exposure potential

SCORE RATING	**Quantity used**	**physical characteristics** how easily is the substance disseminated?	**containment methods used** e.g. type of flask or container
	a	**b**	**c**
1	≤ 1 g	**not easily disseminated,** - non-volatile liquids & solids - no skin absorption	enclosed system, e.g., reflux condenser and flask
10	1 – 100 g	**easily disseminated,** - volatile liquids - volatile solids - solids easily broken into light dusts in the process.	partly closed system test-tubes or flasks
100	≥ 100 g	**very easily disseminated,** - highly volatile liquids - gases - aerosols substances readily absorbed via skin by themselves or carried through in particular solvents used.	open surface of - evaporating basin - beaker - bucket or drum - a surface freshly varnished

Exposure Potential (E) (a) x (b) x (c)				
				Rating
	< 1,000		**Low**	**1**
Exposure potentials of	**1,000 – 10,000**	can be described as being	**Medium**	**2**
	> 10,000		**High**	**3**

Note that the total exposure time is not included here. It is assumed that this is short in terms of minutes and seconds. However, if the operation is frequent or of long duration, then the exposure potential should be moved up a category.

Step 2 - Determine the Hazard Category

		Rating
LOW HAZARD	Includes substances which are: - not GHS labelled, but are in EH40, i.e. have an MEL or an OES, e.g. ethanol. See section 5.1 for general guidance and Appendix 2 for further details.	**1**
MEDIUM HAZARD	Substances labelled H302, H312, H332, H315, H319, H335, H336 (Harmful or Irritant)	**2**
HIGH HAZARD	Substances which: - are corrosive, labelled as H314, H318 - or are acutely toxic (Category 3) H301, H311, H331 - or are category 2 mutagens, carcinogens etc. H351, H361, H362, H371, H373	**4**
VERY HIGH HAZARD	This section includes substances of very high acute toxicity, Labelled H300, H310, H330 It also includes any long term hazards. (Mutagens, carcinogens, Reproductive toxins and Specific Target Organ Toxins) H340, H350, H360, H370, H372	**9**

Many substances will not be found in either the ECHA database or in EH40. Their absence from these groupings may simply mean that they have not been used sufficiently widely to warrant attention. It does not mean that they are without hazard. Manufacturers and suppliers are required by Section 6 of the Health and Safety at Work Act to supply information so that their products can be used safely. This is often done in the form of an SDS. These usually provide enough information to permit an estimate to be made of the hazard. Comparison with data sheets for chemicals which do have GHS Hazard Statements will give points of cross reference. The criteria used in the GHS Regulations for classifying substances as being very toxic, toxic or harmful are given in Appendix 3. If there are still difficulties in making a decision contact the SSERC or a friendly occupational hygienist.

2. If no information is available to the contrary, a sensible precaution is to assume the substance must belong at least the category of ‘High Hazard.

3. Many chemical test kits, e.g. those for measuring the concentrations of different ions in water, contain bottles and sachets of various chemicals often named as “reagent 1 “or “reagent B”. Sometimes manufacturers are reluctant to reveal the chemical identity of the components of the kits and supply only the precautions, which, in their opinion, will adequately control the risks. It is better if you can learn the chemical nature of the contents and be in a position to make your own judgement. For example, we found, only after several requests, that the finely divided powder in

one sachet was cadmium metal! Hopefully this type of information will become more readily available.

Step 3 - Estimate the Risk Index

	Exposure potential		
Hazard category	LOW (1)	MEDIUM (2)	HIGH (3)
LOW (1)	**1**	**2**	**3**
MEDIUM (2)	**2**	**4**	**6**
HIGH (4)	**4**	**8**	**12**
VERY HIGH (9)	**9**	**18**	**27**

A Risk Index of:

1-3	indicates the risk is so low that the work can be carried out on an open bench
4 - 8	indicates the risk is higher, but that the process can probably be safely carried out in a fume cupboard
> 8	indicates the risk **may** be too high for the work as planned to proceed. The process should certainly be looked at closely to see what measures can be taken to make it safer.

The risk index may be reduced by making a number of changes, i.e.

- substitution of particular chemicals by ones which are less hazardous or less volatile

- reduction in scale and

- improvement in methods of containment

No single approach will always be suitable for the preparation of risk assessments and variations on the main method described here will have to be used in some instances.

The Risk Index might appear unreasonably high for some processes involving corrosive substances such as the preparation of solutions of sodium hydroxide by dissolution of pellets or of sulphuric acid by dilution of the concentrated form. The index will indicate the need for an efficient fume cupboard, but most processes using such corrosives can in fact be safely carried out in the open laboratory.

APPENDIX 14

GLOSSARY OF ABBREVIATIONS

ACGIH	American Congress of Governmental industrial Hygienists
ach	Air changes per hour. A measure of ventilation. (The same as rch – the number of room changes per hour)
ASE	Association of Science Education
CLEAPSS	Consortium of Local Education Authorities for the Provision of Science Services
CLP	The Classification, Labelling and Packaging regulations. This is the UK implementation of the Globally Harmonised System (GHS)
CNS	central nervous system
EH40/(year)	Guidance Note giving values of WELs which is usually updated annually
GHS	Globally Harmonised System. The system that seeks to harmonise classification and labelling of chemicals worldwide
HASAWA	Health and Safety at Work, etc Act 1974
HSC	Health and Safety Comission
HSE	Health and Safety Executive
IARC	International Agency for Research in Cancer
ILO	International Labour Organisation
IOELV	Indicative Occupational Exposure Limit Value – The European value that places an onus on member states to produce WELs
IOM	Institute of Occupational Medicine. Provider of workplace health research and consultancy services
LD_{50}	The dose level (mg/kg bodyweight) required to result in the deaths of 50% of a population of test animals when the chemical is administered by the route specified, e.g. oral or dermal
LDLo	The lowest, published dose (mg/kg) known to have resulted in the death of a human. These are clearly not available for every chemical! They may be atypically high or low, but will serve as an indicator. For several chemicals the values for children may be higher or lower than those for adults because of differing susceptibilities.
LEV	local exhaust ventilation
LTEL	Long term Exposure Limit – sometimes used for WEL. This is usually given for an 8 hour period

MDHS	Methods for Determination of Hazardous substances - published by the HSE
MSDS	Material Safety Data Sheet (term used in the US for Safety Data Sheet)
NIOSH	National Institute for Occupational Safety and Health
PPE	Personal protective equipment (goggles, gloves etc.)
rch	room changes per hour. A measure of ventilation. (The same as ach – the number of air changes per hour)
RSC	Royal Society of Chemistry
RTECS	Registry of Toxic Effects of Chemical Substances
SDS	Safety Data Sheet
SSERC	Scottish Schools Education Research Centre
STEL	Short term Exposure Limit – the short term WEL. This is usually given for a 15 minute period
TLV	Threshold Limiting Value - the level to which it is believed a worker can be exposed day after day for a working lifetime without adverse health effects
TWA	Time Weighted Average. The normal workday WEL. Averaged over 8 hours.
WEL	Workplace Exposure Limit, the concentration of a hazardous chemical that is permitted in the workplace