# Topics in Safety

## Topic 10: Using Chemicals

This *Topic* (dated 2014) is an updated version of *Topic 10*, which appeared in the 3rd edition of *Topics in Safety* (ASE, 2001). While the legislation concerning the handling of chemicals has not changed significantly, the changes affecting labelling, supply and other areas are sufficient to make this revision timely.

This *Topic* is written for anyone who uses chemicals, not just chemists. It eschews extensive tables of chemicals and their hazards, concentrating instead on the principles, as other publications are available with more extensive information, e.g. CLEAPSS *Hazcards*[1] and SSERC *Hazardous Chemicals Database*[2].

## Introduction

There is a broad consensus about the chemicals that can be used in school science and under what circumstances. However, problems do arise when the hazards of a particular chemical are re-classified by the regulatory authorities (as is happening at the moment with the implementation of the Globally Harmonised System (GHS) under the Classification, Labelling and Packaging (CLP) Regulation) or when a previously uncommon chemical finds a new use in school science. This *Topic* is intended to address issues such as these.

## 10.1 Assessing the suitability of chemicals for use in school science

### 10.1.1 The nature of risk

The systematic classification of hazards under the CHIP (and now CLP) Regulations and the arrival of COSHH led to a greater awareness of the hazards of substances that have been used routinely in school science for many years. Merely because the hazards are better known does not necessarily mean that the risks are greater or unacceptable. The general public, and sometimes scientists as well, tend to use the word '*safe*' as meaning '*completely safe*' or '*free from risk*'. This is unrealistic and unscientific. Nothing is completely safe[3]. Science teachers should promote the word to mean '*safe enough*' or '*safer than it was*'. There is an important place in chemistry teaching for the spectacular demonstration, which conveys an important chemical message and which students will remember for many years to come, provided that it can be made '*sufficiently safe*'.

### 10.1.2 Justification of Risk

One justification for teaching science is to teach youngsters about the hazards and risks of the world in which they will live and work. This can only be achieved by allowing students to have hands-on experience, in a controlled environment, of substances and activities that present some hazard. Wrapping students in cotton wool would not be a good preparation for life. The difficulty lies in deciding what is sufficiently safe. Does the educational advantage outweigh the risks? For example, the hazards of potassium chlorate(VII) are such that its use is rarely justifiable in schools, potassium chlorate(V) however, although still hazardous, is easily justified for demonstrating the action of a powerful oxidising agent. Similarly it might be inappropriate to give younger students solid barium chloride [ACUTE TOXIN CATEGORY 3 (ORAL), ACUTE TOXIN CATEGORY 4 (BY INHALATION)]

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[1] CLEAPSS Hazcards (**http://www.cleapss.org.uk/secondary/secondary-science/hazcards**)
[2] SSERC Hazardous chemicals database (**http://www.sserc.org.uk/index.php/chemistry-health-a-safety138/hazardous-chemicals276**)
[3] See for example, D. R. Williams (1998) What is safe? The risks of living in a nuclear age. Cambridge: RSC.

but such students could be given 0.1 mol $dm^{-3}$ barium chloride solution [NOT CLASSIFIED AS HAZARDOUS] because they would need to consume implausibly large amounts to do themselves harm. Post-16 students would probably be deemed to be sufficiently trustworthy to handle the solid. Ultimately, it is a matter for the teacher's professional judgement to consider, as part of the risk assessment for an activity, as to whether the educational benefit of an activity outweighs its risk.

### 10.1.3 The role of technicians

In assessing the suitability of some chemicals for school use, it is important to consider the role of technicians. Whereas students will often use relatively dilute, low-hazard solutions, the technician may have had to handle the much more hazardous solute. Because the technician is handling much larger quantities and higher concentrations, face shields, PVC aprons, nitrile gloves, and possibly dust masks must be available. Although it should not be the case, ventilation may sometimes be poor in prep rooms and the technician may well need to use a fume cupboard.

### 10.1.4 Project work

Open-ended project or investigative work is often carried out in school science at all levels including as part of examination requirements. With younger students and/or larger classes, it is best to permit investigations only in relatively safe contexts e.g. using acids and alkalis sufficiently dilute as not to be classified as CORROSIVE. With different groups working on different activities, even the best teacher's supervisory skills are fully tested, without adding health and safety to the problems. More hazardous chemicals should be used only where students can be given clear instructions and supervision is relatively straightforward. In post-16 project work, it is inevitable that some students will want to use chemicals not normally found in schools. Even where students are expected to consider health and safety issues as part of the project, the teacher/lecturer must still check their risk assessments. This is not a job for technicians – the supervising teacher or lecturer has a duty to carry out such a check. With novel chemicals and/or procedures in use, staff may well need a special risk assessment. There could be factors that teachers may not have considered, for example the inability of most school fume cupboards to withstand fumes from hydrofluoric acid. Members should consult CLEAPSS or SSERC.

## 10.2 General principles of risk assessment when using chemicals

We feel a pragmatic approach is best. Over many years ASE, CLEAPSS and SSERC have collected information about accidents in schools. Indeed, much of the time advice given in model (general) risk assessments, such as is found in *Hazcards* or the SSERC *Hazardous Chemicals Database,* is based on information about accidents and near-misses collected over many years. Where the use of a novel substance or activity is proposed we believe it is normally quite straightforward to extrapolate the risks from the known into the unknown, provided that the hazards of the unknown can be identified. The SSERC booklet *Preparing risk assessments for project work in schools*[4] gives useful guidance.

Factors to take into account include the following:

- whether the chemicals will be handled by technicians, teachers or students;
- the nature of the hazards of the chemicals used;
- the amount of chemicals to be used or made;
- the route by which chemicals might be taken into the body;
- if handled by students, their age, ability and degree of responsibility;
- the presence of students with special educational needs, where relevant;

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[4] SSERC (2015) Preparing risk assessments for project work in schools.

- whether students handle the pure substance or only a dilute solution;
- the ability of the teacher to supervise the class adequately (class size, experience and other issues);
- the facilities. e.g. access to a suitable fume cupboard or facilities for heating flammable liquids without using Bunsen burners;
- the availability of gloves (if necessary) and goggles giving chemical splash protection as opposed to safety spectacles;
- training for staff and students, e.g. how to heat a chemical or sniff a vapour safely.

If your employer has provided you with access to model risk assessments for using chemicals, e.g. *Hazcards* or the *Hazardous Chemicals Database,* the risk assessment process becomes much simpler. All you have to do is to check that the model applies to your situation and consider whether any modification is necessary to deal with the particular situation of your school, laboratory or class. Then a simple record is made to show that the risk assessment process has taken place and to convey the significant findings of risk assessment to others, for example by annotating teachers' guides, schemes of work, etc.

Any annotations or other amendments to such documentation must be cleared with the Head of Science to ensure the same procedures are being followed by all.

## 10.3 'Banned' chemicals

### 10.3.1 National bans

There is a common misconception that a variety of chemicals and procedures is banned. This is untrue; under national legislation, almost nothing is banned, even for educational use. In fact, only the following are banned under the COSHH[5] Regulations:

- benzidine (4,4'-diaminobiphenyl) and its salts
- 2-naphthylamine (2-aminonaphthalene) and its salts
- 4-aminodiphenyl and its salts
- 4-nitrodiphenyl (1-nitro-4-phenylbenzene)

Benzene (and anything containing more than 0.1% benzene such as most samples of petrol) was also banned for use in schools until the 2013 revision of COSHH. While there is now no formal ban, the control measures that would need to be put in place, were benzene (or a benzene-containing mixture) to be used, would be very difficult to implement. In most circumstances schools should consider it as still being banned. If schools are considering using benzene, they should contact CLEAPS or SSERC for a special risk assessment.

In 1970, the then DES issued an Administrative Memorandum on carcinogens[6], stating that a range of amines, including α-toluidine, β-naphthylamine and those listed above should not he kept or used

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[5] *The Control of Substances Hazardous to Health (COSHH) Regulations 2005* (6th edition 2013) or, in Northern Ireland, the *COSHH(NI) Regulations 2003*.

[6] Administrative Memorandum 3/70, *The Avoidance of Carcinogenic Aromatic Amines in Schools and Other Educational Establishments,* DES, 1970.

in school laboratories Similar guidance followed in Scotland[7]. It is therefore simplest to consider all of these amines as effectively banned.

There is a range of chlorinated hydrocarbons that are damaging the ozone layer. Under European regulations[8] for some time it has been illegal to supply these for educational or most other uses. Any schools that still hold stocks should dispose of them via a licensed contractor.

Chemicals in this category include

- tetrachloromethane (carbon tetrachloride)
- 1,1,1-trichloroethane

Legislation on explosives (due to be revised in 2014) also bans some chemicals and procedures. For example, the making of gunpowder for demonstration purposes is permitted, subject to a maximum of 100 g, but there is an absolute ban on making mixtures of phosphorus or sulfur with potassium chlorate(V). If an explosive is to be stored (even overnight) there are further constraints.

### 10.3.2 Local bans

Sometimes, education employers have produced local codes of practice, which have included lists of banned chemicals. As employees have a duty to cooperate with their employers on health and safety matters, teachers and technicians must respect any such ban. Employers do have a duty to provide training for their staff and this would surely include informing them of any local bans, which in practice are rare.

It is worth checking the status of any alleged ban: when it was last reviewed, whether it is mandatory or advisory, if there are exceptions for use in post-16 work, etc. It is possible, with good enough reason, to have these restrictions changed. Recently, for instance, a blanket ban on aromatic amines in a local authority was overturned on request after it was pointed out that this would mean the banning of the preparation of paracetamol, a common post-16 practical.

### 10.3.3 Not Recommended

As well as banned substances, there is also a category of **not recommended**. This means exactly what it says: that the substance or procedure is not in general recommended for use in schools. (CLEAPSS and SSERC have lists of such substances). There is no actual ban but, a special risk assessment would be needed before using such a substance in order to:

- evaluate the educational justification for doing something not generally recommended.
- ensure staff are fully aware of the particular health and safety precautions needed to control the risk from this rather special hazard.

In many cases members could obtain such special risk assessments by applying to CLEAPSS or SSERC but might well face some interrogation about why the activity was considered necessary, the facilities available and the skills and experience of the staff involved.

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[7] SF0 Circular 759, *The use of Carcinogenic substances in educational establishments*, SED, 1970; most recently, SED Circular 8/95, *Guidance on the Use of Carcinogenic Substances in Work in Schools*, SF0, 1995.

[8] There have been various pieces of legislation, the most recent one, which seeks to rationalise previous legislation is Regulation (EC) No 1005/2009 of 16 September 2009 on substances that deplete the ozone layer

## 10.4 Hazard and risk when using chemicals

### 10.4.1 Hazard and risk

The Health and Safety Executive (HSE) defines a hazard as anything with the potential to cause harm. This is inherent in the nature of many chemicals. Concentrated sulfuric acid is corrosive. This is an unalterable property of the acid, just like its density.

Risk, on the other hand, is the probability of harm actually being caused by the hazard. Risk depends upon:

- how likely it is that something will go wrong;
- how serious the consequences of something going wrong would be.

### 10.4.2 GHS classification

Under the new CLP Regulation (which implements GHS[9] in the UK), the hazards of chemicals are classified under three headings (see Table 1).

| Hazard Group | Hazard |
|---|---|
| Physical hazards | Explosive<br>Oxidising<br>Flammable<br>Self-Heating<br>In contact with water releases flammable gas<br>Gas under pressure<br>Refrigerated gas |
| Health Hazards | Acute toxin by oral, dermal or inhalation route (cat 1,2,3,4)<br>Corrosive to skin and eyes<br>Eye damage<br>Irritant<br>Mutagen<br>Carcinogen<br>Reproductive toxin<br>Causes damage to organs |
| Environmental Hazards | Toxic to aquatic life<br>Toxic to aquatic life with long-term effects |

*Table 1: CLP hazard groups*

About 70 Hazard Statements are defined in legislation[10]. Examples include

- H272: MAY INTENSIFY FIRE; OXIDISER (e.g. potassium nitrate),
- H260: IN CONTACT WITH WATER RELEASES FLAMMABLE GASES WHICH MAY IGNITE SPONTANEOUSLY (e.g. sodium) and
- H351: SUSPECTED OF CAUSING CANCER (e.g. thiourea).

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[9] *Regulation (EC) No 1272/2008 of The European Parliament and of The Council on Classification, Labelling and Packaging of Substances and Mixtures* (Amended 2013)

[10] *Regulation (EC) No 1272/2008 of The European Parliament and of The Council on Classification, Labelling and Packaging of Substances and Mixtures*, (Amended 2013)

Detailed criteria for assigning these hazard statements are given in guidance from CLEAPSS and SSERC. For example, substances that are classified as acute toxins via the oral route, may cause death or damage if swallowed as described below:

- H302: HARMFUL IF SWALLOWED in moderate amounts
- H301: TOXIC IF SWALLOWED in small amounts
- H300: FATAL IF SWALLOWED in very small amounts.

Some substances may be listed not because they present a hazard themselves but because they form a hazardous substance when in contact with water, acid, etc.

Manufacturers and importers should evaluate the hazards of any substances they place on the market within the EU and submit these evaluations to the European Chemicals Authority (ECHA). ECHA investigates these submissions and determines a ‘harmonised’ classification which is then to be used for that substance across the EU. This process will not be finished for several years and even then will not apply to some substances imported or manufactured in small quantities. As a result, it is possible to purchase chemicals which have different classifications depending on which supplier you use. (See section 10.7.8).

It is important to note, however, that the difference in labelling **may** in fact result from a different formulation or manufacturing route, which may result in different impurities or different levels of impurity, and thus refer to genuine differences in hazard level.

### 10.4.3 $LD_{50}$

There are several different criteria used to assess the toxicity of a substance, the most widely used of which is the $LD_{50}$ value. The $LD_{50}$ (Lethal Dose) is the amount of substance required to kill 50% of the animals in a sample, commonly rats. The figures in Table 2 are scaled as if the animals weighed 1kg and thus are given as mg per kg.

| **Hazard statement** | **$LD_{50}$** (mg/kg, rat, oral) | **Example** | **$LD_{50}$ of substance** (mg/kg, rat, oral) |
|---|---|---|---|
| Not classified as hazardous | >2,000 | Sodium carbonate | 4090 |
| Category 4 | >300 | Copper nitrate | 940 |
| Category 3 | >50 | Barium chloride | 118 |
| Category 2 | >5 | Potassium cyanide | 10 |
| Category 1 | ≤5 | White phosphorus | 3 |

*Table 2: GHS acute toxicity categories*

### 10.4.4 The effect of dilution

The hazard statements in Table 2 apply to the solid. If a solution is used, then the concentration is important as this will affect the volume needed in order to consume a lethal dose. Thus copper nitrate solution needs to be labelled HARMFUL IF SWALLOWED only if the concentration is 1.03 mol $dm^{-3}$ or above. Similarly, barium chloride is labelled TOXIC IF SWALLOWED if the concentration is 1.6 mol $dm^{-3}$ or above, HARMFUL IF SWALLOWED if it is 0.24 mol $dm^{-3}$ or above (but less than 1.6 mol $dm^{-3}$) and of NO SIGNIFICANT HAZARD below that.

It is important to emphasise that, in sufficient quantity, almost any chemical can be lethal – consuming a large excess of sodium chloride or of water has killed in the past! Guidance on how solutions should be labelled can be found in various publications e.g. *CLEAPSS guidance leaflet GL111* or the entries for individual chemicals in the *SSERC Hazardous Chemicals Database*.

### 10.4.5 Long-term health effects

CARCINOGENIC substances (and those classed as MUTAGENS or TOXIC FOR REPRODUCTION) are particularly emotive. There are different classes of these health hazards, just like the acute toxins discussed above, but it is important to recognise that these classes refer to the nature of the evidence for harmful effects: they do not represent a hierarchy of potency.

## 10.5 Exposure Limits

### 10.5.1 Workplace exposure limits

For a limited range of substances, the COSHH Regulations specify Workplace exposure limits[11] (WELs). Mostly, these relate to gases or volatile liquids, as inhalation is the most likely route of intake in most work places. However, if skin absorption could contribute significantly, this is also indicated.

### 10.5.2 Short- and long-term exposure limits

For both types of WEL, the limit is defined as the concentration (in mg $m^{-3}$ or ppm) averaged over a specified period. Two time periods are used: 8 hours, (long-term exposure limits LTELs) and 15 minutes (short-term exposure limits, STELs). Higher doses can often be tolerated if the period of exposure is for a shorter period of time. 15 minute exposure is typical of the way in which chemicals are often used in school science and so STELs are often the appropriate figures to use for classroom work but this might not be true for technicians working in an ill-ventilated prep room.

### 10.5.3 WELs and risk assessments

The model risk assessments often used in school science e.g. CLEAPSS *Hazcards* and the SSERC *Hazardous Chemicals database* will have taken account of WELs when suggesting control measures, such as quantities for particular practical activities. Examples of how to use WELs in exposure calculations can be found in several publications[12]. Sucrose (sugar) has a WEL (STEL) of 20 mg $m^{-3}$; this may be relevant in a sugar bagging plant but is no reason to avoid putting sugar into a cup of tea.

## 10.6 Interpreting Safety Data Sheets

### 10.6.1 Responsibilities for safety data sheets

Under the REACH Regulations[13] a supplier is obliged to provide Safety Data Sheets when substances classified as hazardous are supplied to a downstream user (anyone other than the manufacturer/importer using a chemical in the course of industrial/professional activities). The exception to this is when substances are sold to the general public and sufficient information is provided by other means. Article 31 of the Regulation specifies the information that must be given

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[11] EH40 *Occupational Exposure Limits*, HSE.

[12] See CLEAPSS (2009) *Laboratory Handbook, section 7.9*; or SSERC (2014) *Preparing risk assessments for project work in schools.*

[13] Regulation (EC) No 1907/2006 concerning *the Registration, Evaluation, Authorisation and Restriction of Chemicals*

on Safety Data Sheets. Reference is often made, particularly online, to MSDS (Manufacturers Safety data Sheets). These are American documents and are not written to European standards.

### 10.6.2 Safety data sheets and risk assessments

It is important to stress that Safety Data Sheets are not risk assessments. Risk assessment requires knowledge about the quantities of a chemical to be used, how it is to be used, the skills, experience and training of' the user and other factors that the supplier could not possibly know about. The sheets provide information about hazards. This information is used to carry out the risk assessment.

Many teachers and technicians find Safety Data Sheets very alarming. The information can run to several pages and the toxicological information can be frightening.  Consider the following substance with an $LD_{50}$ of 261 mg $kg^{-1}$ (oral, rat) and described thus:

***Special Remarks on Chronic Effects on Humans:***

> *May cause adverse reproductive effects, maternal and birth defects.*
>
> *May affect genetic material.*
>
> *May cause cancer based on animal data.*

Would the average science teacher or technician think that it is suitable for schools? Yet this is caffeine, something we nearly all consume in small amounts in coffee, tea or cola drinks. Caffeine certainly presents a hazard. Whether there is significant risk depends on the amount and how it is used.

Suppliers, especially those from the USA with its greater tendency for litigation, tend to go overboard in warning about hazards from which there could be little risk in the context in which the substances are used in school science. Despite the guidance available, there are frequently inconsistencies between suppliers about the hazards of, and hence the hazard statements to be used for, a particular chemical, see section 10.7.

## 10.7 Some illustrative examples

In this section we give examples of activities where there are hazards but where the risk can be reduced to acceptable levels with suitable control measures. The intention is that these examples might act as models to show how risk assessment could be carried out in more unusual activities.

### 10.7.1 Explosions of hydrogen

Occasionally there are reports of hydrogen exploding e.g. when being passed over hot copper oxide. Usually, the problem is that excess hydrogen is being ignited at a jet before all the air has been flushed out. There are safe ways of ensuring that all the air is flushed out but, even if it is not, an explosion is not disastrous if the students and staff are well protected by safety screens, eye protection and distance. The key here, as in many similar cases, is (in-house) training for those staff who need to know together with a robust management procedure to ensure that untrained staff do not carry out this activity.  Methane (natural gas) is sometimes suggested as a safer alternative to hydrogen. Whether it is suitable depends on what the educational objectives are; in some contexts, use of methane would be confusing. Hydrogen from cylinders is arguably safer than generating the gas chemically because the large volume of hydrogen which is readily available flushes the air out very quickly. However, hydrogen cylinders, though safer, are not without their own problems, such as storage, movement and maintenance (of regulators in particular).

### 10.7.2  Reactions of sodium and other alkali metals with water

These are some of the more memorable demonstrations carried out in many schools. Even when the school has adopted apparently suitable precautions, there are occasional reports of incidents. e.g. pieces of sodium reacting with unexpected violence and being projected over the safety screen. The problem is sometimes caused by using too large a piece of sodium, or occasionally potassium (perhaps as a result of over-zealous encouragement by the class). Sometimes, against advice, teachers attempt to constrain the sodium in order to collect a sample of gas. Whatever the cause, injury can be avoided by having the safety screens very close to the reaction vessel and students and staff some distance away (e.g. 3 m). A piece of sodium would then need to be travelling almost vertically to fly over the screen and would thus come down into safe, unoccupied space. Even better would be to have three safety screens arranged in a triangle, totally surrounding the reaction vessel, with a fourth placed on top as a ‘lid’. Cooling the water with ice will also help.

### 10.7.3 Different uses: different hazards

Potassium and sodium dichromate(VI) are classified as:

OXIDISING SOLID CATEGORY 2;
ACUTE TOXIN CATEGORY 3 (ORAL), CATEGORY 4 (DERMAL) AND CATEGORY 2 (INHALATION),
SKIN CORROSIVE CATEGORY 1B,
RESPIRATORY SENSITISER CATEGORY 1,
SKIN SENSITISER CATEGORY 1,
MUTAGEN CATEGORY 1B,
CARCINOGEN CATEGORY 1B,
REPRODUCTIVE TOXIN CATEGORY 1B,
SPECIFIC TARGET ORGAN TOXIN ON REPEATED EXPOSURE CATEGORY 1 and
HARMFUL TO THE AQUATIC ENVIRONMENT WITH LONG-LASTING EFFECTS CATEGORY 1.

Normally it is only technicians and post-16 students who handle the solid dichromate(VI) and, because the crystals are usually relatively large, inhalation is implausible in this context. Nitrile gloves should be worn to protect from possible skin contact. Handled this way it is safe enough to use. On the other hand, electrolysis of dichromate(VI) solutions could produce an aerosol of dichromate(VI) mist and so steps would need to be taken to control exposure to this.

The sort of work that students are likely to do with dichromate(VI) involves relatively dilute solutions (less than 0.1 mol $dm^{-3}$), which would be hazardous if swallowed but present much less risk of causing problems by skin contact and could not be inhaled, A school would need to decide whether the class could reasonably be trusted not to swallow the solution.

On the other hand, ammonium dichromate(VI), which has the same hazard statements as the potassium and sodium salts, is used almost entirely because of its interesting and highly memorable exothermic decomposition once ignited. Handling the ammonium dichromate(VI) solid should present no greater risk than the other dichromate(VI) salts. However, as the particles decompose, small specks of chromium(III) oxide are carried into the air. Although low hazard, it is conceivable that they could carry tiny amounts of undecomposed dichromate(VI) which therefore might be inhaled. Consequently, this decomposition should be carried out in a way which prevents inhalation of the particles, e.g by use of a fume cupboard (although this would contaminate the inside) or in a conical flask fitted with a mineral wool plug to act as a filter.

### 10.7.4 Mercury containing devices

Concerns have been expressed about the use in school science of thermometers containing mercury. Mercury is toxic by inhalation and there is a danger of cumulative effects. The European Union has recently (2014) banned the sale of all mercury-containing devices[14], including thermometers. There is no suggestion that existing devices will have to be disposed of, but it would

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[14] Commission Regulation (EU) No 847/2012 of 19 September 2012

make sense for schools to plan the phasing out of mercury containing devices, certainly for all uses where there is an adequate alternative, as they will not be able to replace breakages.

There are alternative ways of measuring temperature, such as liquid crystal strips, digital thermometers and temperature probes. However, none of these is appropriate in all circumstances, if only because of the cost. On some occasions liquid in glass thermometers are needed.

Where accuracy is important, mercury offers a number of advantages, e.g. it responds more quickly (and is thus less confusing in inexperienced hands). It is also less susceptible to errors due to immersion to incorrect depth (and correct immersion is not always possible because of the nature of the apparatus). Provided schools are aware of the hazards of mercury and are vigilant at clearing up any breakages, there is little risk.

There are various alternatives to mercury-in-glass thermometers:

- The most commonly available are ‘spirit’ thermometers which use dyed hydrocarbons. These are quite suitable for primary schools and for much work in lower secondary (although the thread breaks more easily and is harder to re-join).
- For higher temperature work where liquid-in-glass thermometers are still needed, e.g. melting point apparatus, there is a new generation of thermometers that use a particular mixture of hydrocarbons allowing temperature measurement up to 300°C and beyond.

### 10.7.5 Using safer alternatives

Where a safer alternative exists that works just as well, the COSHH Regulations require that it be used. Sometimes the risk can be reduced with no educational disadvantage. For example, sulfuric acid is classed as SKIN CORROSIVE CATEGORY 1A at or above concentrations of 1.54 mol $dm^{-3}$ and SKIN IRRITANT CATEGORY 2 at concentrations between 0.51 mol $dm^{-3}$ and 1.54 mol $dm^{-3}$. Traditionally, ‘bench’ strength sulfuric acid has been 1 mol $dm^{-3}$ or 2 mol $dm^{-3}$ but for most purposes, such as routine tests of the action of acids on indicators, metals, oxides or carbonates, 0.5 mol $dm^{-3}$ works perfectly well and thus should be used.

If the intention is to prepare crystals of a salt, for example by evaporating the water after titration of sulfuric acid with sodium hydroxide, then the use of 0.4 mol $dm^{-3}$ solutions (anything below 0.5 mol $dm^{-3}$ in fact) would result in the need to evaporate a large amount of water. It is more practical to use solutions of higher concentration in this case but that does not invalidate the general point that most work can be done with quite dilute solutions and, where they are satisfactory, they should be used. Bench solutions should normally be below 0.5 mol $dm^{-3}$.

Similarly, when testing for reducing sugars in food, it is far safer for children to heat Benedict’s solution [NOT CLASSIFIED AS HAZARDOUS], although the reaction product, copper(I) oxide is ACUTE TOXIN CATEGORY 4 (ORAL), than Fehling’s solution [SKIN CORROSIVE CATEGORY 1A (for Fehlings solution B)]. As Benedict’s solution works just as well, it should be used. At post-16 level, Benedict’s is not satisfactory in testing for alkanals (aldehydes) and therefore Fehling’s solution should be used there. Alternatively, Sandell’s reagent[15] could be used, although this is a less common reagent and there is the possibility that examiners might not recognise this as a valid test.

### 10.7.6 Microscale

There is an increasing tendency to use microscale[16] techniques for practical chemistry. Microscale chemistry offers many advantages – it is cheaper, since smaller amounts are used, it is quicker and it may be safer. Smaller volumes of gas are produced and so open laboratory working may be possible, avoiding the need for fume cupboards. On the other hand, solutions of higher

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[15] SSERC *Hazardous Chemicals Database*

[16] See, for example, J, Skinner (1997) *Microscale Chemistry*. RSC

concentration are often necessary. Dispensing small volumes requires teat pipettes with the possible risk of accidents arising through misbehaviour or carelessness, especially where concentrated solutions are concerned. However, with increasing experience of microscale chemistry in schools, there is very little evidence of any health and safety problems.

### 10.7.7 Methanal (formalin) solutions

In biology teaching, methanal solution (formalin) has been used in the past for fixing and preserving biological specimens and in microbiology for killing microorganisms before examination. Methanal is classified as

ACUTE TOXIN CATEGORY 3 (all routes),
SKIN CORROSIVE CATEGORY 1B,
SKIN SENSITISER CATEGORY 1,
MUTAGEN CATEGORY 2
CARCINOGEN CATEGORY 1B.

Clearly its use should be avoided where possible but it has been used in small amounts for very many years in biology without evidence of problems.

Traditionally the main use of formalin has been for preserving biological specimens. Nowadays there are safer alternatives. e.g. opresol or propylene phenoxetol, and these should be used for new specimens. However, we would not recommend the automatic replacement of formalin in existing specimens. This may be necessary after a leak or breakage but routinely replacing all formalin could expose technicians to much higher levels of methanal than would otherwise be the case.

For fixing specimens there is no alternative – nothing else works therefore its continued use is justified. Similarly, soaked onto a piece of filter paper, it is placed into an inverted agar plate to kill off the microorganisms prior to examination. Clearly there are other disinfectants which would kill the microorganisms but a liquid sloshing about on the agar gel would destroy or at least damage what was to be observed. The advantage of formalin is that the methanal vaporises from the filter paper so that no liquid comes into contact with the gel. Given the tiny quantities involved, the continued use of formalin is justified in this context as long as steps are taken to avoid skin/eye contact and inhalation of the vapour.

### 10.7.8 Variation in hazard classification

As mentioned in section 10.4.2, 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.

Table 3 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[17] 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.

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

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.*

*Key to Table 3*

| | |
|---|---|
| ***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* |