15 USING CHEMICALS IN SCIENCE

See also *Topic 10 Using Chemicals* in *Topics in Safety* (3rd edition, Hatfield: ASE, 2001; ISBN 0 86357 316 9).

15.1 Types of hazard

The main headings under which chemicals are classified are as shown in the table alongside.

A square label would appear only on bottles; the same symbol inside an equilateral triangle, would appear elsewhere.

In the case of solutions, the hazard depends on the concentration. For example, solutions of sodium hydroxide might be described as CORROSIVE, IRRITANT or LOW HAZARD at concentrations which could all be described as ‘dilute sodium hydroxide’.

Many chemicals these days are supplied with a ‘use-by’ date. This is NOT for health and safety reasons. It merely indicates the date by which the supplier can no longer guarantee the assay and is thus irrelevant to schools.

15.1.1 The CHIP Regulations

The *Chemical (Hazard Information and Packaging) (CHIP) Regulations*, which are up-dated from time to time, specify the criteria for the labelling of dangerous chemicals, and also require suppliers of such chemicals to provide *Safety Data Sheets* for their products. These must contain information, in a specified format, to enable the recipient to take the necessary measures relating to the protection of health and safety at work. Schools, and other users, must keep copies of the *Safety Data Sheets* on file. However, the sheets have to cover all potential users, including large-scale industrial companies. Some of the information can seem very alarming for schools and others using tiny amounts. The information needs to be interpreted, which is part of the role of the tables in this chapter, and other model risk assessments such as *Hazcards*® (CLEAPSS®) and the *Hazchem Manual CD2* (SSERC).

Radioactive substances are covered by different regulations.

The regulations specify a number of categories of danger which relate either to the physico-chemical properties of the substance, eg, OXIDISING, HIGHLY FLAMMABLE or its health affects, eg, TOXIC, HARMFUL, CORROSIVE. There are also associated ‘risk phrases’ (strictly

	Symbol-letter	*Symbol*
VERY TOXIC	T+	
TOXIC	T	
HARMFUL	Xn	
CORROSIVE	C	
IRRITANT	Xi	
OXIDISING	O	
EXPLOSIVE	E	
EXTREMELY FLAMMABLE	F+	
HIGHLY FLAMMABLE	F	
FLAMMABLE	*None*[*]	*None*
DANGEROUS FOR THE ENVIRONMENT	N	
RADIOACTIVE	*None*	

[*] Although no symbol-letter is defined in the legislation for FLAMMABLE chemicals, we have used the symbol F- in the tables in this Chapter.

‘ hazard phrases’) which spell out the nature of the hazard(s) in more detail. For a large number of chemicals this information is contained in the *Approved Supply List*, issued under the *CHIP Regulations*. However if the chemical does not appear in that list then the supplier must classify it in accordance with the procedures laid down in the Regulations.

15.1.2 Exposure limits

The Control of Substances Hazardous to Health (COSHH) Regulations which are up-dated from time to time, lay down *Occupational Exposure Limits* (OELs) for hazardous substances which may be inhaled, eg, gases or volatile substances and dust. These are published annually, by the HSE, in *Guidance Note EH40 Occupational Exposure Limits*.

There are two types of OEL: *Occupational Exposure Standards* (OESs) and *Maximum Exposure Limits* (MELs). MELs apply to the most hazardous substances and represent a limit which must never be exceeded and employers must make every effort to reduce exposure well below this limit. OESs, on the other, hand, represent concentrations to which it is believed that employees can be exposed day after day, without any significant risk.

The whole system of OELs is under review and may well be replaced,

15.1.3 Carcinogens

For a fuller discussion of carcinogens, see *Topic 12, Assessing Carcinogenic Hazards* of *Topics in Safety* (3rd edition, Hatfield: ASE, 2001; ISBN 0 86357 316 9).

The *CHIP Regulations* define three categories of carcinogen.

Category 1 substances. These are known to have caused cancer in humans on the basis of epidemiological studies. They are classified as TOXIC and carry the risk phrase

R45 MAY CAUSE CANCER, or
R49 MAY CAUSE CANCER BY INHALATION.

Some of these are banned by national legislation (shown as XX, or ‘banned’ in the following tables); others are certainly not recommended for school use (shown as NR or ‘not recommended’), and may well be banned in local codes of practice.

Category 2 substances. These should be regarded as if they are carcinogenic in humans. There is a presumption that the chemicals are carcinogenic, generally based on animal studies. They are classified as TOXIC and carry the risk phrase

R45 MAY CAUSE CANCER, or
R49 MAY CAUSE CANCER BY INHALATION.

To some extent the risk depends upon whether they are hazardous by ingestion, inhalation or skin contact, their volatility, and how the chemicals would be used in schools (for example the likelihood of producing dust). Some have major educational benefits, and a degree of judgement has been exercised in classifying some as not recommended (NR), and others as suitable under restricted conditions, such as teacher or technican only (TT), or use under close supervision by post-16 pupils [shown as (Y12) (N13) (S5)].

Category 3 substances. There is cause for concern owing to possible carcinogenic effects. There is some evidence from animal studies. They are classified as HARMFUL and carry the risk phrase

R40 LIMITED EVIDENCE OF A CARCINOGENIC EFFECT.

The evidence is such that in most cases schools could continue to use these chemicals, providing that they exercise caution. Bear in mind that quantities used in schools are very small, and any exposure is usually very brief.

15.1.4 Flammable liquids

There are two parameters which define the hazard posed by flammable liquids:

- the flash point is the lowest temperature at which a liquid gives off vapour in sufficient quantity to ignite with air when a spark or flame is applied;

- the auto-ignition point is the temperature at or above which the vapour from a liquid will ignite spontaneously in the presence of air.

These properties of liquids, together with others such as evaporation rate, will have been taken into consideration when model (general) risk assessments were drawn up.

15.2 Practical procedures using chemicals

The following tables give guidance about the suitability of a range of practical work involving chemicals which may be used in school science. The advice needs to be interpreted with care and with due regard for the actual experience and competence of the pupils in the class.

Table 15.2 lists a number of mixtures which should not be made in schools, as they have been known to be the cause of serious accidents. The remainder of the tables seek to warn, but not prohibit.

Any procedure involving the use of unfamiliar apparatus or chemicals which the teacher has not handled before should be rehearsed before it is demonstrated or used as a class practical.

The absence of any procedure from the lists should not be taken to imply anything.

15.2.1 Disposal of chemical waste

This section, and the accompanying Table 15.1, which appeared in the original (1996) edition have been deleted.

For more information, see *Topic 11*, *Disposal of Waste and Unwanted materials* in *Topics in Safety* (3rd edition, Hatfield: ASE, 2001; ISBN 0 86357 316 9).

Table 15.2 Mixtures which can be dangerously explosive

Practical Procedure	Hazard	Guidance	
		Suitability	Comments
Aluminium (powder) + copper oxides	Explosion	Not generally recommended	These mixtures can explode violently on heating.
Aluminium (powder) + lead oxides	Explosion	Not generally recommended	These mixtures can explode violently on heating.
Ammonia (solution) + iodine	Explosion	Not generally recommended	The mixture is explosive when dry.
Ammonia (solution) + silver nitrate (Tollen's Reagent)	Explosion	Do not store	Make the solution when required and use immediately; do NOT store. An explosion has resulted in a prosecution under the *Health and Safety at Work Act*.
Chlorates(VII) + sulfur or phosphorus	Explosion	Not generally recommended	This mixture can explode violently on heating, or simply on mixing. Has caused a serious accident in a school in recent years.
Chlorates(VII) + concentrated sulfuric acid	Explosion	Not generally recommended	This mixture can explode violently on mixing. Has caused a serious accident in a school in recent years.
Chlorine + hydrogen	Explosion	Not generally recommended	The explosion of this mixture is initiated by light, but hydrogen can be burnt in an atmosphere of chlorine.
Ethanol + concentrated nitric acid	Explosion	Not generally recommended	This mixture may explode after an induction period.
Gunpowder or other known explosives	Explosion	Not generally recommended	Under certain circumstances, making, or attempting to make, some explosive mixtures is illegal under the *Explosives Act* without a licence. Small amounts can sometimes be made, but a special risk assessment would be necessary. Members should apply to CLEAPSS / SSERC for guidance. A gunpowder explosion has resulted in a prosecution under the *Health and Safety at Work Act* because the teacher failed to exercise his duty of care.
Lead nitrate + reducing agents (eg, carbon)	Explosion	Not generally recommended	These mixtures can explode violently on heating.
Magnesium (powder) + silver nitrate	Explosion	Not generally recommended	Explodes violently with traces of water. Has caused several serious accidents in schools.
Potassium manganate(VII) + concentrated sulfuric acid	Explosion + corrosive chemical	Not generally recommended	Explodes on contact.
Trichloromethane + propanone	Explosion	Not generally recommended	This mixture may explode after a (lengthy) induction period.

Table 15.3 Procedures requiring special care

Practical Procedure	Hazard	Guidance		
		Suitability	Comments	
Aerosol cans - use of	Propellant ignition & explosion; hazardous contents	(Y9) (N10) (S2)		Use of laboratory aerosols (freezer spray, ninhydrin) should be carefully controlled. Do not allow personal aerosols, eg, hair sprays.
Biological use of chemicals	Various			Be aware that many of the solvents and reagents used in biology present significant hazards. See Table 15.4, *Handbook, Safeguards, HazChemMan(CD2).*
Burning hydrogen in air	Risk of explosion	Teacher / technician		Ensure hydrogen is pure before attempting to ignite at the generator / delivery tube. Safety screens essential. See *Handbook, HazChemMan (CD2)*.
Burning substances in air	Toxic gases		(FC)	Normally a fume cupboard should be used, unless using very small quantities of substances known not to produce toxic products. See also *Plastics testing* and *Calorimetry*.
Calorimetry – Fuel and food combustion	Explosion, especially with oxygen			Eye protection and safety screens required. Use air instead of oxygen if possible. When using oxygen, flush apparatus with the gas.
Centrifugation	Risk of injury			Ensure that the load is counterbalanced. If the centrifuge does not have a safety interlock, do not open until the rotor is at rest. The centrifuge should be labeled to this effect.
Chromatography	Solvent vapour Locating agent		(FC)	Carry out in a fume cupboard or in a sealed container unless a solvent of low volatility, for example, water, is used. Many are hazardous. See *Aerosol cans*.
Cleaning glassware using chromic acid	Chromic acid is corrosive	Not generally recommended		It is safer to use a commercial laboratory glassware detergent.
Cooling curves, melting point determination	Possibility of toxic vapour			Avoid substances with high melting temperature or harmful vapour. Naphthalene is not recommended except for demonstrations *unless* the tube is loosely stoppered with a plug of mineral wool. Otherwise use hexadecanol or octadecanoic acid. See *Hazcards, HazChemMan(CD2).*
Diffusion of gases	Toxic gases, corrosive liquids		FC	Particular care needed with bromine. Use fresh rubber tubing each time. Demonstration can be done in open laboratory with safety screens, but it is essential to use fume cupboard when dismantling. Sodium thiosulfate solution should always be available. Wear nitrile (not disposable polythene) gloves. Beware of theft of ampoules.
Distillation atmospheric pressure reduced pressure	 Nature of chemicals involved Implosion, scattering of glass			Beware of suck-back and blocked apparatus. For example crude oil (use substitute). Check for cracks or scratches in glass which weaken it. Use safety screens.

Table 15.3 Procedures requiring special care (continued)

Practical Procedure	Hazard	Guidance: Suitability	Guidance: Comments
Drying gases	Blocked apparatus, hazardous substances		Avoid using concentrated acids wherever possible. Some solid drying agents can `cake' together, blocking the apparatus, particularly if the drying tube is not freshly filled. See *Safeguards*.
Dyeing	Some dyestuffs may be irritant		Avoid skin contact and inhalation of dust. Some may be sensitisers. See *Topics*, *HazChemMan(CD2).*
Electrolysis	Nature of chemical products Risk of burns with molten electrolytes		Electrolysis of some solutions may produce toxic gases (for example chlorine from concentrated aqueous sodium chloride). Safe in well-ventilated laboratory if quantities are small. Stop electrolysis as soon as chlorine detected. See *Hazcards*, *HazChemMan(CD2).* FC Molten solids (for example lead bromide) may give rise to harmful dust or fumes: a fume cupboard must be used.
Explosion of gases			Use safety screens and eye protection for all. Risk of hearing damage – one moderate bang is enough. See *Safeguards*.
in plastic bottle	Jet of flame, loud explosion	Teacher / technician	Do not handle bottle once lit. Do not explode more than about 300 cm^3 of hydrogen/oxygen mixture indoors. Larger volumes can be exploded out of doors if spectators are at least 10 m away and demonstrator wears hearing protection or ignites at a distance.
in metal can	Risk of burns	Teacher / technician	See above.
eudiometry	Risk of violent explosion with unsuitable mixtures	Teacher / technician	As eudiometers are made of glass, restrict to small quantities (up to 10 cm^3) of hydrogen/oxygen, hydrogen/air or alkane/air mixtures.
		Not generally recommended	Mixtures of hydrocarbons and oxygen should not be used in eudiometers. Ethyne (acetylene) is particularly dangerous.
Gas cylinders	Danger of falling cylinder causing injury and/or release of gases at very high pressure Chemical nature of the gas		Cylinders should be properly maintained and clamped suitably, both in stores and when in use. They should be moved on a trolley. Set gas flow before connecting to glass apparatus. Certain gases such as oxygen may cause slow deterioration of components. See *Safeguards*, *Handbook*, *HazChemMan(CD2).*
Gas syringes	Nature of the chemicals		Ensure that the piston moves freely, attach a cord to ensure that it cannot fall out of the barrel. Take care that the capacity of the system is sufficient to contain the maximum gas volume that will arise - particularly if heating. Use safety screens if there is a risk of explosion.

Table 15.3 Procedures requiring special care (continued)

Practical Procedure	Hazard	Guidance	
		Suitability	Comments
Heating gases	Risk of explosion if apparatus is sealed. Escape of gas into room		(FC) Use of fume cupboard may be required (for example, with nitrogen dioxide, hydrogen halides). Be aware of the nature of a particular gas.
Heating liquids	Hot liquids spurting (bumping)		Test tubes should never be more than 1/5 full; it is preferable to use a wide tube (boiling tube). Always use a small flame, constantly shake the tube, and point it away from other people. Consider using anti-bumping granules: must be added before heating is started, otherwise may froth up dangerously. Take particular care with sodium hydroxide solution, or mixtures containing it. See *Hazcards, HazChemMan(CD2), Safeguards, Handbook.*
Heating liquids (flammable) eg, ethanol	Risk of fire/burns		Use bath of hot water (or oil) for heating or a purposely-designed electric heater. All flames must be extinguished on the bench where the heating takes place. Kettles are a useful source of hot water. See *Hazcards, HazChemMan(CD2), Safeguards, Handbook.*
Heating solids	Blockage leading to explosion or forcible ejection of solid by formation of gas		The tube should be only partially filled, in a shallow layer along its length to prevent blockage. See *Safeguards, HazChemMan(CD2).*
	Toxic gases		(FC) For example, nitrogen dioxide from nitrates, sulfur oxides from sulfates. See *Hazcards, HazChemMan(CD2).*
	Thermal decomposition may be violent, or produce harmful vapours		(FC) For example, ammonium dichromate. See Table 15.4. (FC) For example, depolymerisation of some plastics; see *Plastics testing*.
Melting-point determinations			See *Cooling curves*.
Named reagents, for example, Brady's reagent Devarda's alloy Fehling's solution Tollen's reagent	Hazard cannot be assessed unless chemical composition is known		Some named reagents have corrosive or toxic components or may be unstable, for example, Fehling's solution requires the use of 4M sodium hydroxide solution. Brady's reagent may contain either concentrated sulfuric or phosphoric acids. Tollen's reagent can explode spontaneously. See *Handbook, Hazcards, HazChemMan(CD2)s.*
Oxidation of ethanol with acidified dichromate(VI)	Risk of reaction mixture spurting from the apparatus	(Y12) (N13) (S5)	Mix the reagents very thoroughly keeping the mixture cool; finally raise the temperature slowly on a water bath.
Pipettes, filling by mouth suction	Risk of chemicals in the mouth	Not generally recommended	Never pipette by mouth: always use a safety device.

Table 15.3 Procedures requiring special care (continued)

Practical Procedure	Hazard	Guidance	
		Suitability	Comments
Plastics testing	Risk of toxic and flammable vapours	(Y9) (N10) (S2)	(FC) The thermal decomposition of pvc leads to the formation of chloroethene (vinyl chloride) which is an established carcinogen. Burning tests for the identification of plastics that could include pvc should be conducted on a very small scale in a fume cupboard.
Polymerisations addition with catalyst condensation	Risk of violent Reaction possible. Hazardous nature of the chemicals		Di(benzenecarbonyl) peroxide (benzoyl peroxide), sometimes used as a catalyst in several organic polymerisations, has been the cause of explosions. See *Safeguards, HazChemMan(CD2).*
Preparation of gases	Nature of chemicals		(FC) Check if fume cupboard required. Check for blockages in the apparatus. Be prepared to avoid suckback of water or other liquids e.g. in a wash bottle by use of a trap.
chlorine	Toxicity		FC A fume cupboard should be used.
	Risk of explosion with wrong reagent		Several accidents have been reported in which concentrated sulfuric acid was used inadvertently in place of hydrochloric acid, leading to an explosion. See *Safeguards, Hazcards, HazChemMan(CD2).*
hydrogen	Risk of explosion if heating or burning		Hydrogen/air mixtures are explosive over the range of 4 to 75% hydrogen. Always ensure that the hydrogen is pure before attempting to ignite at the generator or delivery tube. See *Safeguards, Hazcards, HazChemMan(CD2).*
oxygen	Risk of explosion if using potassium chlorate(V) and manganese(IV) oxide	Not generally recommended	This mixture has given rise to violent reactions when traces of carbon or organic matter were present.
		Y7 N8 S1	It is safer to use `20 volume' hydrogen peroxide solution with manganese(IV) oxide catalyst.
Thermite reactions	Risk of burns	Teacher / technician	These reactions can be very vigorous and shower sparks over several metres. A safer approach is to use a method by which the reaction occurs under water. See *Safeguards, Hazcards, HazChemMan(CD2).*