NATURAL ENVIRONMENT RESEARCH COUNCIL

NERC GUIDANCE ON SAFE STORAGE OF LABORATORY CHEMICALS

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Aim and background

The aim of this document is to provide guidance on the safe storage of chemicals in laboratories within NERC. The risks that arise from poor storage of chemicals in laboratories include:

- unwanted reactions, eg from incompatible chemicals becoming mixed, which may result in generation of heat, fumes, gases and vapours that can give rise to a fire or explosion, toxic risk or cause physical damage with possible environmental consequences.
- escalation of consequences when a small incident that should be easy to control becomes far more serious because other material stored in the vicinity becomes involved.
- reluctance of emergency services to enter a building or laboratory to deal with an emergency situation such as a fire because of doubt over what chemicals are in the lab and how safely they are stored. This can mean that valuable time is lost and a situation that would initially have been easy to deal with leads to major loss. If there is no risk to life only risk to work, no matter how valuable, emergency services will be very unwilling to put themselves at risk.
- the safety of staff, eg other scientists, cleaners, maintenance staff, being placed at risk because, unaware to them, their colleagues have stored chemicals in an inappropriate state or condition, in an inappropriate place and without adequate warning of the hazards.

In most laboratories the quantity of individual chemicals stored is liable to be relatively small and any single container will rarely exceed 2.5 litres in volume or 1 kg in weight. However, the number and variety of chemicals stored can be considerable and this is what often presents a problem – the juxtaposition of many different chemicals with possibly incompatible and potentially harmful properties stored close to each other.

Information and recommendations are given in this guidance to help promote safe practices in managing the storage of chemicals. Indications of what chemicals cannot be stored in close proximity to each other are given together with some guiding principles, which if correctly applied, will considerably enhance safety in storage.

It should be noted that this guidance applies to all storage of chemicals in laboratories and not just to ‘chemistry’ laboratories. Non-chemists often believe they have few problems when it comes to use or storage of chemicals. In reality the variety of hazardous chemicals handled in non-chemical laboratories presents an equal, if not more serious, problem which is compounded by a lack of appreciation and knowledge of chemical hazards.

Some chemicals are so hazardous that storage should be avoided at all costs and if required they should be generated ‘in situ’ within the laboratory equipment. Likewise some reaction products and waste chemicals are very hazardous and are better destroyed in situ rather than being separated, collected and stored awaiting disposal. This may also make decontamination of laboratory equipment safer and easier.

This guidance is not intended to cover bulk storage of large quantities of chemicals such as in a warehouse but could be applied to rooms within, or associated with, laboratories that are designed for or dedicated to storage of laboratory chemicals. A summary and chart derived from the HSE guidance HSG71 ‘Chemical warehousing - the storage of packaged dangerous substances’ on large scale storage (ie warehouse quantities) is given at Appendix 3.

<u>Aspects of safe storage of laboratory chemicals</u>

The following aspects are important to consider in arrangements for safe storage of chemicals:

- **Minimise or restrict** the quantities stored and avoiding over-ordering, which is usually false economy as disposal can cost more than purchase.
- **Authorise** purchases and **maintain records** of location, keeper and quantities.
- Obtain and keep available **hazard information** on the materials purchased and check existing information is up to date.
- **Labels and signs** eg on <u>bottles</u>: date of purchase, name of the chemical, name of purchaser or ’keeper’, orange CHIP (Chemicals [Hazard Information and Packaging for Supply]) hazard sign, key risk and safety phrases; on <u>cupboards</u>: signs indicating nature of hazard presented by chemicals stored within); on <u>rooms</u>: see last paragraph of section on ‘Segregation’.
  Note: new hazard signs are being introduced by the Globally Harmonised System of Classification and Labelling of Chemicals or GHS, which will be gradually introduced until it entirely replaces CHIP in 2016 – see Appendix 4;
- Utilise **containers** that are appropriate and well sealed (‘parafilm’ can be useful to better seal caps for malodorous or volatile chemicals). Containers must not be over-filled and adequate ‘ullage’ or free headspace allowed that will permit expansion of the contents without over-pressurising the container. Some chemicals will require vented caps to allow escape of any gases evolved during storage.
- Use **secondary containment** (eg spill trays, outer containers or over-packs such as ‘safepaks’) to minimise the consequences of spillage, leakage or breakage.

- Choose an appropriate **storage position**, for example, do not store bottles on the floor where they may be kicked, locate large containers on lower shelves and avoiding stacking containers on top of each other.
- Exercise **care in handling** eg not picking up heavy fragile containers by their neck; avoiding catching the bottom of glass vessels on lips or edges of containment trays / shelves and using appropriate carriers, trolleys, trays etc. during transport.
- **Tidiness** of storage **-** breakages and spillages are far more likely if storage arrangements are cramped, overcrowded or there is limited visibility.
- **Stock control** with rotation of material (eg marking with 'use by' dates or 'date opened') and periodic clear-outs. Some materials will deteriorate or decompose on extended storage.
- **Share stocks** eg scientists are often unwilling to use someone else's stock. However, if each scientist maintains their own individual stock of chemicals, the quantities stored will become excessive and disposal charges will escalate. Encouraging sharing and developing trust in each other's working methods will help.
- The quantities of hazardous chemicals stored within the laboratory may need to be subject to **restriction** eg for highly flammable liquids.
- Regular **disposal** of waste or unwanted / unused chemicals will reduce the quantities stored and release valuable storage space.

Maintaining an **inventory** of chemicals stored in any laboratory or on site is useful. Electronic chemical inventory management systems are available on which chemicals can be checked in at delivery / receipt and even create bar code labels. When a centrally managed chemical store is available such systems can be used to record each use, location of chemicals and allow for re-ordering when stocks are low.

Emergency services may be unwilling to enter buildings or labs in the case of a fire where there is uncertainty as to what chemicals may be stored within. It is also useful if this inventory can be accessed remotely and not just within the lab itself as this will help considerably if access to the storage area is impossible. Even if exact quantities of chemicals stored are not known, a notice indicating general / maximum quantities of hazardous materials stored and classes of chemicals displayed on the lab door (see Appendix 5 for suggested signs) or at the building entrance will be of great assistance. It is useful if this inventory can be accessed remotely eg for reference if called up at home in the middle of the night or if access to the building is prohibited.

Principles of safe storage

Three principles can be applied to help provide safe storage of laboratory chemicals.

- **Segregation**
- **Separation** and
- **Ventilation**

These are physical or engineering controls that are intended to contain or control the risk at source so are high up on the desired hierarchy of safety precautions.

The aims should be: to **segregate** incompatible chemicals from each other; to **separate** hazardous chemicals from unsuitable conditions for reasons of their toxicity, flammability or reactivity (eg preventing exposure to: unsuitable temperatures; air; moisture; sources of ignition; sunlight; unauthorised access etc); and to provide adequate **ventilation** which will remove or dilute malodorous, noxious, toxic or flammable vapours and prevent their build-up.

Segregation

The key incompatibles to segregate from each other are strong acids from strong bases and strong oxidisers from organic or flammable materials. If mixing of these incompatible materials occurs due to spillage, breakage or leakage the danger is one of reactions which generate heat, toxic vapours, fire and even explosion. Appendix 1 gives a non-exhaustive list of incompatibilities of common laboratory chemicals and what may go wrong should they mix.

Haphazard storage on shelves is to be avoided, not least because breakages and spillages are more likely to occur when searching through a muddle of bottles.

An alphabetical arrangement is better than haphazard storage but can lead to problems with incompatibles being stored next to each other (see appendix 2 for some examples of problems that may arise). Storing chemicals together on open shelving may be acceptable for low risk materials. However, certain specific classes of chemical must be segregated from each other, eg in different storage cupboards or, where this is not possible, in separate secondary containment and not stored above / close to each other

Typical classes requiring segregated storage in a laboratory are:

- Acids
- Bases
- Highly flammable liquids (ie those with a flash point of 32°C or lower)
- Chlorinated solvents
- Malodorous or noxious chemicals
- Toxic chemicals and poisons
- Oxidising reagents
- Highly reactive compounds eg pyrophoric or air / moisture sensitive
- Controlled drugs
- Regulated chemicals (eg subject to chemical or biological weapons legislation)
- Temperature sensitive compounds

- Radioactive materials *(note: this is a specialist topic and reference must be made to your local rules / procedures and Radiation Protection Supervisor)*

In a normal laboratory not all these materials would necessarily need to be segregated from each other, but it is important the segregation suggested in the following paragraphs occurs.

Strong mineral acids (eg sulphuric, nitric, and hydrochloric) must be kept apart from strong bases. Even storage in the same cupboard on different shelves with spill trays is inadvisable eg hydrochloric acid in the same enclosure as ammonia solution will cause a white deposit of ammonium chloride to form over everything.

Highly flammable liquids (HFLs) should be kept away from other materials. In theory storage of HFLs with water would not cause a problem, however it is a waste of flammable solvent cupboard space since the volume of flammable storage cupboards should be kept as small as possible. Chlorinated solvents, although they are generally non-flammable and even possible extinguishants, should not be stored together with HFLs as toxic vapours such as phosgene could be generated should a fire occur. Some weak organic acids may also be highly flammable or have a flash point just above 32° C, eg acetic acid, so in theory should be segregated from other HFLs. However, in practice their storage within a solvent cupboard is probably better than many alternative locations and certainly better than an acid storage cupboard.

Volatile and malodorous materials eg mercaptans should be stored in a ventilated enclosure such as a cupboard beneath a fume cupboard fitted with forced ventilation. Such ventilated cupboards can be used for storing volatile chlorinated solvents. Certain amines, eg diethylamine, are not only organic bases and corrosive but also volatile, highly flammable and possess a very unpleasant odour so pose particular storage problems. Although in theory they should be stored in flammable cupboards (flammability taking precedence over corrosivity in storage terms) these cupboards are normally unventilated and the build up of smell is so unpleasant the cupboard is rendered unusable. On balance, it is probably best to keep quantities of such malodorous material to a minimum, well sealed (eg with parafilm around the cap) and store in a secondary outer container in a ventilated cupboard.

Labelling of the segregated storage location with an indication of the hazards presented by the stored material is useful. The correct sign to display, on the outside of the door to the cupboard, is either the yellow hazard warning triangle with a suitable pictogram and wording although the GHS sign (see Appendix 4) is an alternative. Occasionally the sign provided and displayed on the cupboard is a transport label, such as a diamond with wording and pictograms, which is not technically correct but is better than a hand-written sign or none at all.

It is not usually necessary to label the door to the laboratory with an indication of all the hazards posed by the chemicals stored within, except for dedicated storerooms such as for HFLs, as this could lead to ‘sign blindness’. It is best practice to display no more than about four safety signs on a laboratory door ie for the principal hazards and precautions such as biohazard (with containment level) or ionising radiation, gas cylinder storage, PPE required and possibly only the most serious chemical hazard. A regularly updated general reference notice listing the classes of chemicals stored within and their maximum quantities is useful on the outside of the laboratory door to inform emergency services who may attend out of hours (see Appendix 5).

Separation

Physical separation

In a laboratory situation adequate separation can be achieved by means of storage cupboards which physically divide incompatible classes of hazardous chemicals. The cupboards may need specific properties or provide separation by means of distance. They will also need to provide secondary containment (eg spill trays or bunded shelves) and security (eg locks / bolted to wall).

Special means of separation

Some chemicals will need specialist storage methods to separate them from incompatible conditions eg under nitrogen to exclude air or moisture, under controlled temperature, or other specialist storage arrangements (eg gas cylinders).

Separation by distance

On some occasions separation could be afforded by distance alone. Separation by distance is more normal for buildings eg dedicated flammable stores or gas cylinder compounds but it can also be applied to chemicals in laboratories as a means of keeping incompatibles a safe distance apart or minimising risk from more than one flammable cupboard becoming involved in a fire. However, the limited size of many laboratories may preclude this. Where explosive atmosphere (ATEX) provisions apply, distance may be used to define flameproof areas around sources of vapours in which all sources of ignition must be excluded.

Materials of construction

The storage facility will need to serve several functions such as being strong enough to carry the weight of the stored material, being compatible with the materials stored, easily cleanable and, in the instance of flammable liquids, having suitable resistance to the passage of flame or hot gases and not to distort, melt or lose integrity when subject to extreme heat, for a sufficient period of time. Many shelving systems use movable ‘pegs’ to support the shelves and allow variation in spacing. Fixed shelves are preferred but, where variable height systems are used, care must be exercised to ensure the pegs are: all in place, sufficiently strong to bear the load; level; secure and cannot be easily dislodged. For storage of corrosives, the materials must be compatible with and resistant to the corrosive nature of the stored material. Wooden shelves or carcasses are not suitable for storing corrosives or oxidisers unless lined with a resistant material. It should be noted that the accelerators used in some adhesives or two pack epoxy systems may be oxidising agents and if so should not be stored on wooden shelves.

Glass shelves for storing chemicals are not ideal as they can be shattered and may get attacked by certain materials eg hydrofluoric acid.

For storage cupboards for corrosives, or for metal storage cabinets located out of doors, steel and aluminium components must be treated to resist attack eg by corrosion resistant paint or powder coating, being galvanised, anodised or cadmium plated or they will rapidly deteriorate and lose their ability to store materials safely.

Secure against unauthorised use / access / theft

Control of access will be required for certain classes of chemicals, which will include:

- Extremely toxic
- Poisons
- Controlled drugs
- Regulated chemicals eg certain chemical weapon precursors, biological toxins and explosives / de-sensitised explosives
- Certain ‘high risk’ other materials depending on local procedures eg carcinogens, teratogens, mutagens and highly reactive
- Radioactive *(note: reference must be made to your local rules / procedures and Radiation Protection Supervisor)*

Extremely toxic materials and poisons should be stored in a locked secure cupboard (which may need to meet certain standards of security and be bolted to a secure structure), although it is probably best not to label this as the ‘poisons’ cupboard as it could draw unwanted attention. Regulated chemicals (eg chemical weapon precursors and certain biological toxins) are subject to strict controls which may include the need for a licence, annual returns and restrictions on quantities held. They will need the same treatment and could be stored in the same location as poisons. It may also be decided that certain chemicals which, although not legally defined as poisons, could be used to intentionally harm persons, may need to be stored in the same location. Controlled drugs will need to be treated in a similar manner with secure storage but stored separately to poisons and the storage location must not labelled as containing controlled drugs. They are also subject to strict legal controls which are beyond the scope of this document to describe. Fridges used to store these materials may need to be lockable.

For many of the chemicals that need to be covered by secure storage, a book or electronic record to record the date, the chemical being used, the person withdrawing the chemical, the amount used and the countersignature by an authorising person is advisable. Specific approval of purchase and use of such high risk chemicals is also strongly recommended.

Secondary containment eg spill trays, safepaks (available from VWR BDH)

Separation will also include preventing or reducing spread of materials from spillage or leakage beyond the confines of the store cupboard. This is normally achieved by using lipped trays or shelves, also known as 'bunded' shelves. The same principle can also be applied to rooms, such as flammable liquid storerooms, where the floor is bunded and the threshold of the door is raised to contain and prevent the spread of any spilt material beyond the confines of the room. All approved flammable liquid storage shelves should have lipped / bunded shelves but it is often found that the shelves are inserted upside down with their lips facing downwards and offer no spill protection at all. The lips must face upwards so that any spilt material is contained. Some flammable liquid storage cupboards will have lipped shelves with holes in their bottom that allow spilt liquid to flow through and collect in a sealed sump in the base of the cupboard. The best design of bunded shelf has a perforated insert which raises the storage surface up to the same level as the lip but allows spilt liquid to be captured in the shelf below. This helps avoid the common problem of catching the bottom of glass containers on the raised lip of the shelf as they are removed, which can cause the container to fracture. A similar principle can be applied to solvent storage rooms whereby the whole floor is lowered to form a sump above which is installed a grid flooring to give a surface which is level to that to the outside and facilitates moving wheeled trolleys in and out of the storeroom.

The material of construction of the secondary containment shelf must be compatible with the materials stored. For solvents it will usually be metallic shelves but for corrosives a plastic shelf may be more appropriate.

Safepaks are plastic secondary / over-packing containers with a screw lid which are a useful method of providing extra separation and containment for extremely toxic or volatile / malodorous chemicals. They might also provide a means of allowing segregation of incompatibles when storage in different cupboards is impossible to achieve but this should only be considered as a means of last resort. Safepaks are available from VWR / BDH (Prolabo) in sizes of 100 ml, 500 ml, 1000 ml and 2.5 l (both standard and Euro Winchester sizes) and can be re-used. The 100 ml to 1000 ml sizes are available in clear plastic which allows the label, condition and contents of the inner container to be checked before opening. They also allow safe transfer of very hazardous or malodorous materials from the storage location to contained areas such as fume cupboards before opening.

Cold storage

Many hazardous chemicals need to be stored under controlled temperature conditions to prevent or delay their deterioration. This is often achieved in the laboratory by means of a refrigerator. Laboratory fridges must be dedicated to this purpose and never used to store food or beverages. 'Frost free' fridge designs are desirable as they prevent ice build-up and remove the need for frequent defrosting.

If fridges are used to store HFLs, they must be of a ‘non-sparking’ design and labelled to indicate this. However, it should be noted there is no accepted or formal definition of what consists a ‘non-sparking’ fridge and it is not necessarily the same as IEC Ex n protected equipment. It is essential that the interior of a fridge used to store HFLs contains no sparking components such as lights / switches or thermostats and is sealed, with no openings or pathways down which flammable vapours from the inside can travel to sparking or non-protected components mounted externally.

Solvents with a flashpoint below 4ºC such as diethyl ether are able to create an explosive atmosphere within the confined, unventilated enclosure of a fridge. Ideally, all fridges in laboratories should be purchased as non-sparking from the supplier.

Storage of materials within fridges may be haphazard and occasionally bottles are seen stored on top of each other, which must not be allowed. Strict control must be exercised and redundant material regularly cleared out. Many fridges have storage compartments in their door which are tempting to use for storing small bottles, which may have very hazardous contents. If the door pocket is overfull or is not made of a continuous piece of material and the fridge door is opened too vigorously, these bottles will fall out onto the lab floor and can split / fracture. It may be best to remove the door storage compartments altogether to eliminate the temptation to use them for inappropriate storage.

Flammable storage

The quantity of HFLs (ie defined for these purposes as having a flashpoint of 32°C or below) stored should be kept to a minimum. The maximum quantity of HFLs that may be stored in a laboratory should not exceed 50 litres and must be kept in a fire resisting storage cabinet. If the volume of individual containers of highly flammable liquid is small, ie no more 500 ml or hopefully significantly below this, a risk assessment might be able to show that storage of these containers in the open lab is acceptable but ideally they should still be stored in a fire resisting cupboard or bin.

A suitable HFL or solvent cupboard will have the following features:

- at least 30 minute fire-resisting construction.
- sealed carcass (with bonded or otherwise fire stopped joints).
- high melting point (ie greater than 750 ºC) hinges and fittings.
- display a flammable hazard warning sign (yellow / black triangle with a flame symbol) and the wording ‘highly flammable liquid’.
- no vents or, where there are vents, vents which are protected against. passage of flame by means of a fire damper (not just a flame arrester).
- bunded storage (eg shelves with lips turned upwards).
- rebated doors or lid (preferably with seals).

- lockable door fastening which will not allow the doors to warp in the event of a fire eg a bayonet fitting closure (‘espagnolette’).

Whilst this guidance is not primarily concerned with storage of compressed gases, which is a specialist topic meriting its own document, there may be a number of small (ie below 500 ml capacity) pressurised gas canisters or cartridges such as aerosol or propellant cans used and stored within labs. Often these cans will utilise a flammable gas such as methane, propane or butane as their propellant and so present a flammable and explosion risk. Ideally these cans should be stored in a dedicated gas store which is in a well ventilated, safe place outside the laboratory. However, provided the number and volume of flammable gas canisters is kept to a minimum (less than 6), they may be stored within the laboratory, preferably in a flameproof or ventilated cupboard.

Flammable storage cupboards should not be used for storing any other chemicals.

Special storage

In addition to temperature, there may be other conditions or environments from which it is necessary to separate the stored chemical so requiring special conditions and methods of storage. In the main these will be required for highly reactive, explosive or air / moisture sensitive materials. Methods of storage may include: separate storage cupboards or rooms; use of sealed secondary containers; storage under nitrogen; precautions to avoid contact with moisture (eg in a fire fighting situation); precautions to prevent deterioration or drying out under storage and rapid turnaround and / or disposal of unused material so preventing return to storage. Other special storage conditions may include precautions to help prevent deterioration eg use of stabilisers or avoidance of exposure to light / ultra violet radiation. Sometimes, in order to keep reagents or solvents dry, liquids are stored over additives like sodium ‘wire’ and special care will then be needed when washing out or disposing of used storage containers eg if rinsing with water. Molecular sieve is a more modern and safer alternative to sodium.

Pyrophoric materials, ie having UN class 4.2 or 4.3, which can ignite spontaneously under standard conditions with no external source of ignition (often reacting violently on exposure to water, the atmosphere or both) are particularly hazardous and require careful storage. Examples often found in synthetic chemistry laboratories, as many are catalysts or specialist reagents, include:

- Borane / diborane (air sensitive)
- Grignard reagents (water sensitive but normally generated in situ)
- Lithium aluminium hydride (water sensitive)
- Palladium on charcoal (air sensitive)
- Raney nickel (air sensitive)
- tert-Butyl lithium (moisture and air sensitive)

- Sodium borohydride (water sensitive)

The special storage provisions indicated here may also need to be included with other storage requirements, such as refrigeration, segregation and ventilation.

In some cases the special storage requirement may be as simple as keeping the substance under water or wetted and hydrated. One example is picric acid, which must be kept wet at all times and never allowed to dry out or it will become liable to explode if subject to shock or friction.

Ventilation

Ventilation is often an essential requirement for safe storage of hazardous chemicals. Its main function is to allow dilution and extraction of vapours or gases that may escape / seep out from containers during storage so they no longer present problems from the viewpoint of noxious smell, hazardous personal exposure or creation of an explosive atmosphere.

The most common ventilated storage location in a laboratory is in specially constructed cupboards located beneath a fume cupboard. However, not all such cupboards will be ventilated and checks should be made if you are unsure. They can normally be identified by the existence of a spigot or circular aperture within their rear wall but the existence of airflow through this aperture should be checked as the flexible hose can fall off or be omitted. The flexible hose forms a ‘bleed’ tube which connects the interior of the cupboard to the extract duct of the fume cupboard. The volume extracted through the bleed tube does not need to be large, perhaps a few litres per second, and if the cupboard is well sealed this is not an issue since it will maintain the cupboard at a slight negative pressure. Excessive extract on such a storage cupboard should be avoided as it will reduce the fume cupboard extract volume and affect its efficiency, possibly inducing unwanted draughts in the vicinity of the open face of the fume cupboard. It should be noted that a fume cupboard itself is an enclosure primarily designed for undertaking work in and should not be used as means of providing ventilated storage unless dedicated to this purpose with other work excluded.

Materials that should be stored in a ventilated cupboard include:

- Malodorous or noxious substances such as mercaptans and mercaptoethanol (which should be in well sealed containers in sealed secondary containers which are only opened in a fume cupboard)
- Volatile non-highly flammable substances such as chlorinated solvents
- Formaldehyde
- Volatile, malodorous amines (in secondary containers)

Ventilated cupboards should not be used for storing HFLs unless they also meet the requirements for highly flammable liquid storage cupboards AND have dampers fitted to the extract and any inlets that will shut off the ventilation in the event of a fire. This is because the flow of fresh air would permit the HFLs contained within to become involved in the fire and add to its severity. Fitting flame arresters to vents is insufficient as the vapours can still escape and ignite on the exterior of the arrester.

Natural ventilation by vents / air bricks to outside atmosphere is an alternative to mechanical ventilation in achieving the necessary air exchange and can be very useful for store-rooms, especially those for flammable liquids. The vents should be of sufficient number, at low and high levels to cater for both heavier and lighter than air vapours or gases and in at least two walls, ideally those opposite each other, and aim to achieve an air change rate of at least 5x an hour.

Appendix 1: Common laboratory chemical incompatibilities (note: this list is not exhaustive and merely indicates some frequently encountered examples)

(Adapted from Imperial College NHLI guidance 'Safe storage of chemicals in the laboratory', originally derived from the American Chemical Society publication: 'Safety in Academic Chemistry Laboratories').

Chemical	**Incompatible with**
Acetic acid	Chromic acid, nitric acid, hydroxyl compounds, ethylene glycol, perchloric acid, peroxides, permanganates
Acetylene	Chlorine, bromine, copper, fluorine, silver, mercury
Acetone	Concentrated nitric and sulphuric acid mixtures
Alkali and alkaline earth metals	Water, carbon tetrachloride & other chlorinated hydrocarbons, carbon dioxide, halogens
Aluminium*	When finely divided with iron oxide or other metallic oxides (thermite reaction)
Ammonia (anhydrous)	Mercury, chlorine. Calcium hypochlorite, iodine, bromine, hydrofluoric acid (anhydrous)
Ammonium nitrate	Acids, powdered metals, flammable liquids, chlorates, nitrites, sulphur, finely divided organic combustible materials
Aniline	Nitric acid, hydrogen peroxide
Arsenicals	Any reducing agents
Azides	Acids, heavy metals such as silver, gold, lead, copper
Bromine	See chlorine
Calcium oxide	Water
Carbon (activated)	Calcium hypochlorite, all oxidising agents
Chlorates	Ammonium salts, acids, powdered metals, sulphur, finely divided organic or combustible materials
Chromic acid, CrO_3	Acetic acid, naphthalene, camphor, glycerol, alcohol and flammable liquids in general

**many other finely divided free metal powders are extremely reactive and particle size is a major factor in increasing reaction rate eg with metal turnings*

Chlorine	Ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, benzene, finely divided metals, turpentine
Chlorine dioxide	Ammonia, methane, phosphine, hydrogen sulphide
Copper	Acetylene, azides, hydrogen peroxide
Cumene hydroperoxide	Acids (organic and inorganic)
Cyanides	Acids
Flammable liquids	Ammonium nitrate, chromic acid, hydrogen peroxide. nitric acid, sodium peroxide, halogens
Fluorine	All other chemicals
Hydrocarbons	Fluorine, chlorine, bromine, chromic acid, sodium peroxide
Hydrocyanic acid	Nitric acid, alkali
Hydrofluoric acid (anhydrous)	Ammonia (aqueous or anhydrous)
Hydrogen sulphide	Fuming nitric acid, oxidising gases
Hypochlorites	Acids, activated carbon
Iodine	Acetylene, ammonia (aqueous or anhydrous), hydrogen
Mercury	Acetylene, fulminic acid, ammonia
Nitrates	Acids
Nitric acid (conc)	Acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulphide, flammable liquids and gases, copper, brass, any heavy metals
Nitrites	Acids
Nitroparaffins	Inorganic bases, amines
Oxalic acid	Silver, mercury
Oxygen	Oils, grease, hydrogen, flammable liquids / solids / gases
Perchloric acid	Alcohols, acetic acid / anhydride, bismuth and its alloys, organic materials, paper, wood, grease, oils

Peroxides, organic	Acids (organic or mineral), avoid friction, store cold
Phosphorus (white)	Air, oxygen, alkalis, reducing agents
Picric acid	Strong oxidizing agents, bases, most common metals, ammonia, strong reducing agents, also do not allow to dry out as will explode with friction / impact
Potassium chlorate and perchlorate (see also chlorates)	Sulphuric and other acids
Potassium permanganate	Glycerol, ethylene glycol, benzaldehyde, sulphuric acid
Selenides	Reducing agents
Silver	Acetylene, oxalic acid, tartaric acid, ammonium compounds, fulminic acid
Sodium	Carbon tetrachloride, carbon dioxide, water
Sodium nitrite	Ammonium nitrate and other ammonium salts
Sodium peroxide	Ethanol, methanol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulphide, glycerin, ethylene glycol, ethyl actetate, methyl acetate, furfural
Sulphides	Acids
Tellurides	Reducing agents

Note: A useful reference on chemical incompatibilities and other reaction hazards is ‘Bretherick's Handbook of Reactive Chemical Hazards’ published by Academic Press.

Appendix 2: Some problems with alphabetical storage (from Texas A&M University Guidance: http://safety.science.tamu.edu/chemstorage.html)

- Acetic acid + acetaldehyde - small amounts of acetic acid will cause the acetaldehyde to polymerize releasing large amounts heat
- Acetic anhydride + acetaldehyde - condensation reactions can be violent -- explosive
- Acrolein + ammonia, aqueous - extremely violent polymerization reaction of acrolein and any alkali or amine
- Aluminium metal + ammonium nitrate - potential explosion
- Aluminium metal + antimony trichloride - aluminium metal burns in the presence of antimony trichloride vapour
- Aluminium metal + any bromate (or chlorate or iodate) - finely divided aluminium plus these compounds produces potential explosion that is detonated by heat, percussion, friction or light.
- Aluminium chloride - self-reacting upon prolonged storage, explosion occurs when container is opened
- Ammonium nitrate + acetic acid - mixture will ignite especially if acid is concentrated
- Cupric sulphide + cadmium chlorate - explode on contact
- Hydrogen peroxide + ferrous sulphide - vigorous reaction, highly exothermic
- Lead perchlorate + methanol - explosive mixture if agitated
- Maleic anhydride + magnesium hydroxide - potentially explosive reaction
- Mercury nitrate + methanol - mixture has potential of forming mercury fulminate, an explosive
- Nitric acid + nitrobenzene - mixtures of nitric acid and nitrobenzene may be detonated
- Potassium cyanide + potassium nitrite - potentially explosive mixture if heated
- Silver + tartaric acid - explosive mixture
- Silver oxide + sulphur - potentially explosive mixture
- Sodium + selenium - reaction attended by burning
- Sodium + silver bromide, silver chloride, silver fluoride, or silver iodide - forms impact-sensitive systems
- Sodium + sulphur - reaction proceeds with explosive violence
- Sodium + stannic halides - forms impact-sensitive mixtures
- Sodium cyanide + sulphuric acid - release of HCN gas, death

Appendix 3 HSE Guidance on bulk storage of chemicals

The HSE produce guidance for bulk storage of chemicals in warehouses. This uses classes based on UN packing groups which are the basis of the transport classifications.

The HSE guidance for bulk storage of chemicals in warehouses (HSG71) specifies levels of separation between the classes, where 'keep apart' is at least 3m separation (B) [except for toxic gases stored outside (B / C) where it may be 1m], 'segregate' (C) must be a durable physical barrier of at least 30 minutes fire resistance, and 'isolate' (D) where a dedicated building is recommended. In a laboratory or small dedicated chemical storeroom situation these levels of separation are impossible to meet and are not strictly necessary due to the much smaller quantities involved.

"HSE Storage table.doc"

Appendix 4 – GHS signs

Physical hazards

Exploding bomb

Usage

- Unstable explosives
- Explosives, divisions 1.1, 1.2, 1.3, 1.4
- Self-reactive substances and mixtures, types A, B
- Organic peroxides, types A, B

Flame

Usage

- Flammable gases, category 1
- Flammable aerosols, categories 1, 2
- Flammable liquids, categories 1, 2, 3
- Flammable solids, categories 1, 2
- Self-reactive substances and mixtures, types B, C, D, E, F
- Pyrophoric liquids, category 1
- Pyrophoric solids, category 1
- Self-heating substances and mixtures, cats 1, 2
- Substances and mixtures, which in contact with water, emit flammable gases, categories 1, 2, 3
- Organic peroxides, types B, C, D, E, F

Flame over circle

Usage

- Oxidizing gases, category 1
- Oxidizing liquids, categories 1, 2, 3
- Oxidizing solids, categories 1, 2, 3

Gas cylinder

Usage

- Compressed gases
- Liquefied gases
- Refrigerated liquefied gases
- Dissolved gases

Corrosion

Usage

- Corrosive to metals, category 1

no pictogram required

Usage

- Explosives, divisions 1.5, 1.6
- Flammable gases, category 2
- Self-reactive substances and mixtures, type G
- Organic peroxides, type G

Health hazards

Skull and crossbones

Usage

- Acute toxicity (oral, dermal, inhalation), categories 1, 2, 3

Corrosion

Usage

- Skin corrosion, categories 1A, 1B, 1C
- Serious eye damage, category 1

Usage

- Acute toxicity (oral, dermal, inhalation), category 4
- Skin irritation, categories 2, 3
- Eye irritation, category 2A
- Skin sensitization, category 1
- Specific target organ toxicity following single exposure, category 3

- Respiratory tract irritation
- Narcotic effects

Not used

Exclamation mark

- with the "skull and crossbones" pictogram
- for skin or eye irritation if:
  - the "corrosion" pictogram also appears
  - the "health hazard" pictogram is used to indicate respiratory sensitization

Health hazard

Usage

- Respiratory sensitization, category 1
- Germ cell mutagenicity, categories 1A, 1B, 2
- Carcinogenicity, categories 1A, 1B, 2
- Reproductive toxicity, categories 1A, 1B, 2
- Specific target organ toxicity following single exposure, categories 1, 2
- Specific target organ toxicity following repeated exposure, categories 1, 2
- Aspiration hazard, categories 1, 2

no pictogram required

Usage

- Acute toxicity (oral, dermal, inhalation), category 5
- Eye irritation, category 2B
- Reproductive toxicity – effects on or via lactation

Environmental hazards

Environment

Usage

- Acute hazards to the aquatic environment, category 1
- Chronic hazards to the aquatic environment, categories 1, 2

no pictogram required

Usage

- Acute hazards to the aquatic environment, categories 2, 3
- Chronic hazards to the aquatic environment, categories 3, 4

Appendix 5 – Possible signs for doors (delete box if not stored within lab to avoid confusion or unnecessary concern)

HAZARDOUS CHEMICALS STORED WITHIN LAB XXX			
 **ACIDS** Quantity not exceeding x litres **BASES** Quantity not exceeding x litres	 **FLAMMABLE SOLVENTS** Quantity not exceeding (stored in solvent cupboard) x litres	 **TOXIC MATERIALS** List and max quantity x l / x g x x x x	 **OXIDISING AGENTS** List and max quantity x l / x g x x x x
 **HIGHLY REACTIVE MATERALS** List and max quantity x l / x g x x x x	 **EXPLOSIVE MATERALS** List and max quantity x l / x g x x x x	 **OTHER HARMFUL/IRRITANT** Max quantity x l / x g	 **HARMFUL TO THE ENVIRONMENT** Max quantity x l / x g

HAZARDOUS CHEMICALS STORED WITHIN LAB XXX

 **ACIDS** Quantity not exceeding x litres **BASES** Quantity not exceeding x litres	 **TOXIC MATERIALS** List & max quantity x l / x g x x x	 **HEALTH HAZARD** List & max quantity x l / x g	 **OTHER HARMFUL/IRRITANT** Max quantity x l / x g	 **GAS CYLINDERS** **(**number & size) Flammable: Oxidising: Toxic: Non-flammable:
 **FLAMMABLE SOLVENTS** Quantity not exceeding (stored in solvent cupboard) x litres	 **OXIDISING AGENTS** List & max quantity x l / x g x x x	 **HIGHLY REACTIVE** List & max quantity x l / x g x x x	 **EXPLOSIVE MATERALS** List & max quantity x l / x g x x x	 **HARMFUL TO THE ENVIRONMENT** Max quantity x l / x g