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From Cradle to Grave: How to Manage Chemicals in Between

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The phrase “cradle to grave” is one coined to describe the national Resource Conservation and Recovery Act’s ([RCRA](#)) regulatory statements with regards to handling hazardous waste from the time it is generated until the time it is properly disposed of. However, I believe it is an appropriate phrase to describe the care we should take throughout the lifetime of a chemical’s existence, even before it is classified as waste. Aren’t we truly responsible for a hazardous substance from the time we receive it until the time we properly dispose of it?

How does the lifetime of a chemical proceed? Well, first the stork delivers... Okay, really, some manufacturer synthesizes, purifies, bottles and stores chemical reagents just waiting for a chemist to buy them. Up until this point, the manufacturer is responsible for these chemicals. Once the chemicals have reached their new home, we (the buyers) become responsible. We must use these chemicals properly, then store and/or dispose of them in an ethical, safe and legal manner. In undergraduate laboratory situations, most chemicals are purchased, a portion of the chemicals used and then the remainder is stored until it has either been used up or has become useless. This is when the chemical is officially “dead” or “waste”.

This paper will reflect general federal regulatory concerns (your state or local authorities may have more stringent regulations), as well as provide suggestions for purchasing and storing chemicals through the end of their “life”. Other papers presented in this course will focus on the disposal concerns of chemicals. This paper will also reflect my experiences as the laboratory manager for a fairly small chemistry department catering to the undergraduate student, including many students who perform undergraduate research. Those of you currently enrolled in undergraduate research programs and/or those of you planning to attend graduate school may find very similar conditions to which I will refer in this paper.

Acquisition

The acquisition of chemicals is most strongly correlated with regulations that fall under the Occupational Safety and Health Administration ([OSHA](#))*. OSHA is the federal agency that is concerned with the safe manufacturing of the chemical, as well as the safe handling and usage of the chemical once it has reached its new home in a laboratory. The Department of Transportation ([DOT](#)) regulates the proper packing, shipping and labeling of the chemical during its trip from the remote location of the manufacturer to the laboratory. As with most regulations, there is a crossover between agencies that oversee any aspect of handling chemicals.

It should be noted that OSHA only regulates employees that are exposed to chemical hazards, **not students. Your current status as a student excludes you from OSHA’s regulations (unless you are a student employee). However, this paper is written under the assumption that you will likely move into the position of employee working in a chemical laboratory sometime soon!*

The way you will go about purchasing a chemical reagent in the future will likely be through a standard procedure established by your employer/department/laboratory. The basic rules of purchasing a chemical amount to this:

1. Don’t buy more if you already have some useable reagent in stock... Check with others in your department (if you do not have a central stockroom) to see if they have any of this reagent that you can use. The increasing number of computerized chemical inventory systems makes this increasingly easy to do.

2. Don't buy more than you need. Bulk buying is attractive because of price breaks, but if the reagent will be compromised in any way over time, that excess will become useless to you and you will pay for disposal. Also, think of the money going into storing the large quantities of chemical (stockroom clerk time, inventory time, proper storage cabinets, safety, potential fines for storing too much of a hazardous chemical, etc.).
3. Don't purchase chemicals unless you have the proper facilities and equipment to handle and store them.
4. Avoid purchasing highly toxic chemicals whenever possible!
5. Avoid the temptation of free chemicals (i.e., donations). Once the chemical has entered your realm, it is your problem. If you accept chemical donations, make sure they are in good condition and that you will use them in the very short term.

You will not likely be involved directly in the middle ground between ordering and receiving, but shipping is something you should always keep in mind when ordering a chemical. There are shipping and hazard costs involved and sometimes the price to ship is greater than the price of the chemical itself. As previously mentioned, the DOT regulates the shipping process. For more details with regard to regulations for shipping hazardous materials, see [Title 49 of the Code of Federal Regulations, Subtitle B, Chapter 1](#) (part 172 has a lot of information of relevance).

Receiving of a chemical will also likely be through a standard procedure established by your employer/department/laboratory. Personnel trained in the OSHA Laboratory Standard ([29 CFR 1910.1450](#)) or "Right to Know" training (as required by [29 CFR 1910.1200](#)) should handle chemicals in the receiving process. The receiving person may also be required to have DOT training ([49 CFR Subtitle B, Ch. 1](#)). In any event, the chemical package should be delivered as directly as possible to the end user for entry into the inventory and proper handling/storage. The arrival date should be recorded on the bottle and/or in the inventory system.

Our baby has arrived. Now we need to keep track of it.

Inventory and Tracking of Chemicals

You (or your employer) will be responsible for maintaining a chemical inventory. An inventory in its simplest form is mandated by OSHA's Hazard Communication regulation ([29 CFR 1910.1200](#)).

"Employers shall develop, implement, and maintain at each workplace, a written hazard communication program which at least describes how the criteria specified in paragraphs (f), (g), and (h) of this section for labels and other forms of warning, material safety data sheets, and employee information and training will be met, and which also includes the following:

1910.1200(e)(1)(i) A list of the hazardous chemicals known to be present using an identity that is referenced on the appropriate material safety data sheet (the list may be compiled for the workplace as a whole or for individual work areas); and,"

OSHA is mandating that a list of chemicals be present and that each chemical can be directly correlated with a Material Safety Data Sheet (MSDS). OSHA provides no other requirements with regard to inventory in this Standard. Your institute may also be required to report chemical inventory to EPA under the Emergency Planning and Community Right-to-Know Act ([EPCRA](#)), otherwise known as Title III of the Superfund Amendments and Reauthorization Act ([SARA](#)). This inventory reporting is related to state and local emergency planning and response. More information about requirements for the required inventory reports can be found the EPA's website under [Chemical Emergency Preparedness and Prevention](#).

Aside from the regulatory side, if you are going to run the most efficient laboratory you can, someone must be accountable for knowing what is in stock and trying to minimize duplication and build-up of chemicals. This makes good economical and environmental sense. It is obvious that duplicating chemical purchases is a waste of money, but many do not look into the future and see the end cost of disposal and the potential harm to the environment. Centralized purchasing and inventory would be ideal in terms of these savings, but most of us find ourselves in situations where individual divisions (usually individual departments or research groups) will be in control of their own budgets, purchases and inventories. These individual divisions tend to be very territorial about their “stuff”, which makes the overlapping of purchases difficult to prevent. Every effort should be made for cooperation between individual divisions to “share” whenever possible for an overall savings to the institution.

There are many means of establishing an inventory and tracking system. It can be as rudimentary as index cards or as sophisticated as commercial software packages. At the very least, a simple spreadsheet would be an adequate way to track chemicals. In my opinion, chemical name, CAS number, location of the bottle (room number), and size of the bottle are the very basics. If you can track the amount of chemical left in the bottle (assuming the bottle is being shared), that can be convenient for the user also.

If you are interested in what commercial inventory software exists, perform a search on your favorite search engine to see the options. My experience has been with the ChemSW[®] software package called [CISPro 2000[®]](#). This system is more complex than a traditional undergraduate college chemistry department needs, but it also allows for a lot of information to be entered about the physical properties and hazards of chemicals. It comes with many special features and extras that can be added on. It also allows for the production of barcodes to help track the chemicals. Unfortunately, that requires a rather costly scanner! The barcode/scanner system would be ideal for tracking as it would be instantaneous. We still use the barcode as a quick reference to the chemical and location, and it makes physical inventory much easier. As new chemicals are acquired, they are entered into the inventory as soon as possible and delivered to the end user. In our system, we also deliver the appropriate barcode along with the package with directions to apply the barcode as soon as the bottle is removed from the package.

For tracking, we have implemented a color-coded check-out/check-in system. When a chemical bottle leaves one room (normally our central stock) and is moved to another, the responsible party fills out a pink form that asks for the responsible party's name, the barcode on the bottle, and where the bottle will be stored while under this person's care. If the person empties the bottle, he or she fills out another form (yellow) that is handed in with the barcode from the bottle, as well as verification that the bottle was either recycled or destroyed. If the person no longer needs the chemical, the bottle is returned to stock and the user fills out a green form with the barcode information. The forms and a collection envelope are available in each of the teaching stockrooms, the central stockroom and the major research labs. Weekly or bi-weekly, the manager of the inventory collects the forms and updates the inventory. This system allows one person to be in control of the database, which cuts down on the possibility of mistakes or catastrophes (with a database of 3000 chemicals hand-entered, the loss of a database could be considered catastrophic!). Centralizing access to your inventory may be desirable and web-based software is also available. Whatever system is decided on, inventory is a must!

Copies of the inventory should be made available to appropriate administrators and to the local fire authorities (whether or not you are required to do so by EPCRA). By supplying lists of chemicals by room, emergency personnel can evaluate and classify the hazards associated with that particular room ahead of time, so that they can respond appropriately in the case of an emergency. We keep several secure computerized copies of the inventory, as well as submitting a hard copy to our Environmental, Health and Safety office, as well as the local volunteer fire department.

A physical inventory should be done periodically (annually as a minimum) to both compare to the computerized records and to check the condition of the bottles themselves. When checking these bottles, check the integrity of the container (condition of the caps, rusty cans, cracking plastic, etc.) and the integrity of the chemical (see the section on Storage of Chemicals below). If something seems amiss, get rid of it!

We have a way to keep track of where the baby is; now we have to dress it appropriately.

Labeling Bottles

It is OSHA that regulates the labeling of the chemical bottles we purchase ([OSHA 29 CFR 1910.1200](#)) and store. However, it is the EPA that dictates how chemicals should be labeled once they are determined to be waste – whether waste means the chemical has been used in a procedure or has become unusable (“waste-like”). It is the DOT who determines labeling in shipping. Neither DOT nor EPA’s labeling requirements will be addressed in this paper. OSHA’s rules for labeling in a typical chemistry lab are outlined in [OSHA 29 CFR 1910.1200\(f\)](#) and can be summarized as:

1. Identify the hazardous chemical(s) in the container. *((f)(1)(i) & (5)(i))*
2. Identify hazard warnings either with words, pictures, symbols, or some combination thereof. You must provide at least general information regarding the hazards of the chemicals, which in conjunction with the required MSDSs will provide employees with the specific information regarding the physical and health hazards of the chemical. *((f)(1)(ii) & (5)(ii))*
3. Identify the name and address of the manufacturer, importer, or other responsible party. *((f)(1)(iii))*
4. The above information must be in English. *((f)(9))*
5. The original manufacturer’s label should not be removed or defaced. *((f)(8))*
6. Some sort of group labeling system can be used as long as the group of containers is readily identifiable and the first four criteria listed here are fulfilled. *((f)(6))*
7. Labeling is not necessary if there was a transfer from a properly labeled container to another container if the contents are intended to be used immediately and only by the employee who made the transfer. *((f)(7))*

Current manufacturer labels should be adequately marked for OSHA standards, but if you come across an old chemical reagent bottle that you just can’t part with, the label may not be compliant. I have seen many chemicals purchased pre-1975 with only a name and a manufacturer listed on the label. The standard ([29 CFR 1910.1200 \(f\)](#)) tells us that these labels are not “grandfathered”. The standard says:

*“The chemical manufacturer, importer, distributor or employer need not affix new labels to comply with this section **if existing labels already convey the required information.**” ((f)(10))*

If you have a chemical this old, you should carefully consider whether or not it is still usable, and if it is deemed useful, add a label to the back listing the hazard warnings. It is the right thing to do for the safety of the employees and any emergency responders that will handle the chemical in the future

In addition to and in complement with the OSHA standard, the American National Standard Institute (ANSI) adopted a labeling standard (ANSI Z129.1) which requires the following^{1,2}:

- Signal words - DANGER, WARNING, CAUTION; highly toxic materials shall be marked POISON
- Key words to describe main hazards (Flammable, Harmful Vapor, etc.)
- Precautionary measures useful in preventing physical harm to the individual
- Instructions in case of exposure
- Notes to physician for emergency treatment
- Instructions in case of fire or chemical spill
- Instructions for chemical handling and storage

It should be remembered that ANSI issues standards that are recommendations. ANSI's standards are only legally binding if a regulating agency, like OSHA, adopts the standards.

If you do get into the business of labeling secondary containers, there are many options, so remember to at least cover the minimal regulations set forth by OSHA. There are several popular systems for rating chemical hazards that you may want to add to your labels (one may even be mandatory depending on local laws or the chemical hygiene plan at your institution). The Hazardous Materials Identification System[®] (HMIS[®] – controlled by [the National Paint and Coatings Association](#)) is one such system. This method uses a color and numeric rating system to highlight the hazards associated with the areas of health (blue) and flammability (red). Until just recently, the HMIS[®] system included a reactivity rating also. It has been changed with the latest version (HMIS III[®]) to replace reactivity with “physical hazard” (orange). In addition, the HMIS[®] system includes an area for identifying appropriate personal protective equipment (PPE). The [HMIS rating system](#) is based on a numeric scale of 0 to 4 with 0 being low to no hazard and 4 being extreme hazard. The ratings for specific chemicals are published and sold through the National Paint and Coatings Association, as well as through some retailers (just search the web!). Occasionally, HMIS ratings can be found on MSDSs.

J.T. Baker also has a numeric rating system called [SAF-T-DATA™](#). This system rates in the categories of health, flammability, reactivity, and contact, and with the same basic numeric scale as the HMIS[®] system. This labeling system also provides written hazard information in the Canadian Worker Hazardous Materials Information System ([WHMIS](#)) format and storage recommendations (see Storage of Chemicals below). SAF-T-DATA™ ratings can be obtained from [J.T. Baker MSDSs](#), which are readily searchable on the web.

One of the most recognizable systems is the National Fire Protection Association's ([NFPA 704](#)) “fire diamond”. The [NFPA rating systems](#) include the same basic color scheme as HMIS[®], but rates on instability/reactivity (yellow) and specific hazard (oxidizer, use no water, acid, etc.), rather than physical hazard and PPE. The numeric system is essentially the same as the previously mentioned systems. The NFPA ratings for specific chemicals are published and sold through the [NFPA](#), as well as through many retailers. NFPA ratings can also be found quite regularly on MSDSs.

The major downfall to the NFPA system is that the ratings reflect immediate contact information (not extended exposure) and usually in the scenario of a fire or spill. The HMIS[®] and SAF-T-DATA™ rating systems are much more appropriate for a laboratory worker who would get repeated exposure to the chemical (chronic effects).

None of these rating systems are OSHA required, but they are widely recognizable and provide valuable information at a glance. If these systems are used, **there must be specific training** for employees who will come into contact with these chemicals/labels. The NFPA, HMIS[®] and SAF-T-DATA[™] systems **do not** fulfill the OSHA standard alone. Written hazard warnings must be present, including target organs (if applicable). The emergency overviews located near the beginning of most MSDSs provide the signal words, key words and target organs that ANSI recommends. Fisher Scientific and J.T. Baker both supply such emergency overviews on their MSDSs that can be obtained easily through searches performed through the [Vermont SRI-MSDS database](#). Additional valuable hazard warnings can be obtained from Chemical Laboratory Information Profiles (CLIPs) located in issues of the [Journal of Chemical Education](#) and [The Laboratory Chemical Safety Summaries](#) located in the back of *Prudent Practices in the Laboratory*. For more on the ANSI terminology and written hazard warnings, see the website [Right to Know Labels, Design Hints, and Frequently Asked Questions](#).

Some more sites for information on labeling, hazard warnings, pictograms, and sample labels can be found at the following links:

- [Cornell labeling system online](#)
- [Interpretation of Chemical Labels](#)
- [International Occupational Safety and Health Information Centre, Identification, Classification and Labelling of Chemicals](#)

My experience in undergraduate teaching and research labs has left me with a few things to add about labeling:

- Labels really should contain the complete name of the compound in English. The temptation of chemical symbols and chemistry shorthand (EtOH, MeOAc, etc.) should be avoided. The rules listed above lead me to believe that OSHA may allow this so long as there is a reference guide available to decipher the symbols. However, a quick glance should be enough to at least give an indication of the identity of the chemical.
- Smaller containers, which may not allow for an acceptable label (the famous sample vials we all have around), can be placed in a compatible secondary container with an appropriate label.
- It is very frustrating to clean up stockrooms when groups of vials coded with non-sensical letters and numbers are found. Vials of “unknowns” (as used in a lab procedure) and sample vials coded with pages in a lab notebook must have a key readily available that allows for the identification of the compounds (as the name corresponds to the available MSDS). The key must be in English, and there must be hazard warnings on the key pertaining to the compound group as a whole or if the hazards vary, the different hazards for each compound.
- In our labs, we tend to repackage** smaller amounts of reagents to distribute to other members of the department as well as students in the teaching labs, and often provide dropper bottles for common aqueous acid, base and salt solutions (again, for common use). OSHA is not entirely clear on the repackaging issue, but we have been working our way toward changing all labels to include the full chemical name, the chemical formula (where appropriate) and the hazard warnings.

***There is a two-fold safety reason for repackaging in smaller bottles (not to mention the logistics). First, the less reagent provided, the less waste there is, and the lower the risk of chemical injury. When a whole 100 gram bottle of sodium chloride is allowed into the laboratory and 10 students are asked to take about five grams each, the bottle will come back empty, and there will be some messy bench tops and balances! However, if you distribute 75 grams of sodium chloride among 3 smaller vials, the vials will generally return to you with some sodium chloride left. This phenomenon is much more extreme*

with liquids and aqueous reagents where the chemical injury part becomes more of a concern! Second, with each student or faculty member digging his/her scoop into one stock bottle, the risk of contamination increases. On the lighter side of things, this scenario leads to a useless bottle of chemical reagent that now needs to be properly disposed. This of course can be costly, depending on the chemical. On the darker side of things, this scenario could lead to a build-up of incompatible chemicals that could go “boom” at any time.

As an additional note with “relabeling”, my experience has led me to find that clear packing tape (individual rolls purchased at the local department store) is an invaluable tool in the lab and stockrooms. We typically generate labels in a word processing program, print them off on plain paper and then adhere them to the bottles with the packing tape. The benefits to this include:

- So far, I have not seen this tape fail to stick to a chemical reagent bottle, and last!
- When you want to remove them, just soak the bottle in water for a little while and they just fall right off (I have seen exceptions to this if the label were on for a long time and the bottle was stored in a corrosive cabinet).
- It protects the ink on the label very well.
- It is cheap compared to pre-cut labels made for printers.

I have had endless troubles with labeling tape and “sticky” labels. If they do stick in the first place, they never come off. If liquid dribbles down the side of the bottle, often the ink runs so badly that the contents become unidentifiable. The protective layer provided by the packing tape really prolongs the lifetime of a label.

The baby is dressed. How will we shelter it and when do we say goodbye?

Storage of Chemicals

Most chemicals will be stored in some sort of a stockroom during their lifetime. The key elements involved in the storage of chemicals are the facilities themselves (the room, the shelving units/cabinets, etc.), how to go about “filing” chemicals in a safe and efficient manner, and knowing when it is time to stop storing a chemical.

Many things must be taken into consideration when establishing a chemical stockroom. Unfortunately, financial resources tend to be the limiting factor on how “safe” a facility’s stockroom is. I am not an engineer, so I cannot speak to the ideal laboratory or chemical stockroom design, nor is there room in this paper to discuss all the aspects that should be discussed. I will, however mention a few key things to think about. Some basic information about laboratory and stockroom design can be obtained from [Flinn Scientific’s website](#), as well as from OSHA’s non-mandatory [Appendix A from 29 CFR 1910.1450](#). The primary concern is the safety of the employee entering/working in the stockroom. Standard safety precautions are needed, but federal (OSHA and NFPA especially) and local regulatory requirements need to be addressed as well.

- Ventilation in lab spaces, stockrooms and some cabinets is mandatory. The Laboratory Standard ([29 CFR 1910.1450](#)) directly states the requirement that fume hoods be functioning properly. Both the Hazard Communication ([29 CFR 1910.1200](#)) and the Laboratory Standard ([29 CFR 1910.1450](#)) point out the need to keep employee’s exposure to chemicals below the permissible exposure limits (PEL). A good ventilation system (including fume hoods) is the best way to ensure that this regulation is satisfied. Ventilation systems are beyond my expertise, and again could be the subject of a whole other paper. For more information, see

Prudent Practices in the Laboratory, [Chapter 8](#) and OSHA's suggestions with regard to ventilation systems in [Appendix A from 29 CFR 1910.1450](#).

- Chemical stockrooms, like any laboratory, should be equipped with all standard safety equipment such as safety showers, eyewashes, smoke alarms, sprinkler systems and fire extinguishers.
- Ideally, the chemical stockroom should have a communication system – a phone or an intercom, so that in the event of an accident, authorities can be reached easily. If your stockroom is not equipped with a phone, either do not enter alone, or bring a cell phone along just in case!
- It is also desirable to have more than one exit from a stockroom in the event of an emergency. The stockroom should be maintained in such a way that neither of these alternate exits ever becomes blocked.
- Clear signage for all of the safety equipment as well as all emergency shut-off valves (electrical panels, gas lines, air lines and water lines) should exist. It is helpful to have maps for the room printed up with these features outlined!
- Temperature and humidity controls should also be in place, with special consideration for chemicals with low flash points and those that are water reactive.

There are some regulations with regard to chemical storage. The NFPA and OSHA ([29 CFR 1910.106](#)) regulate the amount of combustible/flammable liquid, the container material used to store the combustible/flammable liquid and the storage cabinet design and usage for flammable materials. OSHA regulates storage/inspection of compressed gas cylinders ([29 CFR 1910.101](#)), referring to the regulations designed by the [Compressed Gas Association](#) (storing gas cylinders will not be further discussed in this paper as it is a topic worthy of its own paper). Other than these regulations, I am unaware of any other clear statement about storing classes of chemicals (OSHA has some standards for specific chemicals). In OSHA's suggestions with regard to chemical storage ([Appendix A from 29 CFR 1910.1450](#)), it is stated:

“Toxic substances should be segregated in a well-identified area with local exhaust ventilation (221). Chemicals which are highly toxic (227) or other chemicals whose containers have been opened should be in unbreakable secondary containers (219). Stored chemicals should be examined periodically (at least annually) for replacement, deterioration, and container integrity (218-19).”

As a result of the regulations discussed above, it is obvious that special, dedicated flammable cabinets are necessary in a chemical stockroom. Tables [4.2](#) and [4.3](#) in *Prudent Practices in the Laboratory* outline some of the NFPA storage requirements. Though it is not specifically stated in a regulation, the corrosive nature of acids and their vapors provide enough justification to have them contained in a separate, vented cabinet (nitric acid should have its own separate compartment and if you use perchloric acid, it should be stored separately as well). It may be desirable to store strong bases in a separate dedicated cabinet as well. Here, the vapors are not the issue, but rather a secondary containment system as the bases themselves are highly corrosive. I am also a strong believer in a dedicated cabinet for ammonia solutions and any halogens that may be around the lab. Ammonia gas will escape most caps over time, so it is best to store it in a vented cabinet. The halogen vapors create the same problem, but are even more irritating if they escape into the laboratory! Other chemicals tend to be stored on open shelves or other purchased or built-in cabinets.

Some chemicals require refrigeration. Dedicated explosion proof refrigerators are necessary for storage of any combustible, flammable, or explosive chemicals that require refrigeration. When storing chemicals in a refrigerator, it is a great idea to have secondary containment, as the compounds we tend to

place in refrigerators have high vapor pressures and/or tend to be reactive in some way (often organometallics, alkenes, bicyclic compounds). By providing secondary containment, another barrier is placed in the way of escaping and intermingling vapors. Aside from the possibility of reaction between vapors, this reduces odors in the lab. Also, the containers we keep in refrigerators are often small (usually because of cost) and secondary containment keeps these small bottles/vials from falling over and possibly breaking. Clean, delabeled, recycled wide mouth reagent bottles work great for this. Any container used as secondary containment should be cleaned and dried thoroughly. All previous labeling should be removed. Also make sure that the container/lid materials are compatible with the chemical you are storing in it as well as those around it. Wide-mouth bottles can be purchased from any standard laboratory vendor as well. These refrigerators should be labeled clearly as “Chemical Storage Only” and “No Food or Beverage Allowed”.

Shelving unit and storage cabinet design and material are important to consider. There are debates over which materials are best for shelving units/cabinets that are used in chemical storage. If you correlate price to superiority, then it would seem that wood is the best all-round material. In comparing 45 gallon flammable cabinets, NFPA approved wooden cabinets are slightly more expensive than the traditional steel cabinets of the same capacity (through [Fisher Safety](#) and [Flinn Scientific](#)). Wooden corrosives cabinets are more than double the price of traditional steel cabinets of equivalent capacity (again, through Fisher and Flinn). Plastic cabinets are an alternative for corrosives. Polypropylene cabinets are about double the cost of steel cabinets of equivalent size (Fisher Safety). Metal shelving units and cabinets are the cheapest and can be purchased from almost any vendor dealing in safety products and/or industrial furniture.

In general, my experience with shelving units and cabinets tells me that wood is the most chemically resistant, and will last the longest in a chemical storeroom. Moreover, I would strongly recommend the use of wood cabinets for the storage of corrosive chemicals, as it does not take long for corrosives to destroy a metal cabinet! Whichever material is chosen, my experience has also taught me that the application of Con-Tact® paper on shelves in a stockroom lengthens the lifetime of those shelves. I once ran an independent test on the durability of Con-Tact® paper when directly exposed to a series of chemicals. The Con-Tact® paper stood up very well to direct contact with acetone, hexane, 12 M hydrochloric acid, 6 M sodium hydroxide and ether. It did not fare as well upon contact with dichloromethane or oxalyl chloride, but not many materials do! A note should be made that all strong oxidizing agents often react violently with organic materials, so these materials should not be stored on wood shelving.

Shelving units should be secured to a wall and/or floor to prevent tipping. Shelving units with lips on the front of them are desirable to prevent individual bottles from being easily knocked over or from rolling off of the shelf. An alternative to this is to purchase plastic bins that hold reagent bottles. This is an especially convenient alternative when there are a series of smaller bottles/vials associated with the stock bottle. In a freshman chemistry lab, we typically provide six sets of reagents for our students. I was able to purchase very nice plastic bins (through [C&H](#)) that hold the stock bottle of reagent plus 6 distribution bottles. When they are needed for an experiment, the bin can just be pulled from the shelving unit and the instructor is ready to go. We have also made an investment in plastic kitty litter pans for storing hazardous waste bottles as well as other types of bottles.

Once you have shelving and cabinets, the chemicals must be organized on those shelves and in those cabinets. Several systems for organizing chemicals are suggested throughout the profession, but the traditional ABC method is not a good one! It is very easy to end up with incompatible chemicals right on top of each other! Major chemical vendors, such as [Fisher Scientific](#) and [J.T. Baker](#) often have color-coded compatibility systems. Commonly, red is for flammable, blue is for toxic, yellow is for reactive/oxidizer, white is for corrosive and then there is a color designated for relatively low hazard chemicals (Fisher uses gray, while Baker is orange). The key thing to keep in mind is compatibility. You do not want to store incompatible chemicals right next to each other. Your textbook, *Prudent Practices in*

the Laboratory, lists some incompatible chemicals in [Table 3.9](#) and families of incompatible chemicals in [Table 3.10](#). MSDSs will give some information on incompatible chemical combinations, but if you have any concerns, *Bretherick's Handbook of Reactive Chemical Hazards* is an excellent reference.

Once the right home is found for the chemical, its “shelf life” will need to be considered. As mentioned previously, an annual check-up on chemicals is a very prudent idea. The age and exposure of a chemical can affect the purity in many cases. Chemicals that can be air-oxidized can often be identified by a discoloration of the chemical. Chemicals that react (mildly) with water in the air may also appear to be discolored. Hygroscopic salts will appear “wet” with time. Given enough time, hygroscopic salts may become solutions! Some solvents can become “wet” with minimal exposure to air. How serious these “contaminations” are is dependent on your use of the chemical. A “wet” salt being used to make a solution of magnesium chloride for a qualitative experiment being performed to identify the presence of chloride ion is not commonly seen as a problem. Using this same salt to perform an analytical experiment would be a problem. Using “wet” ether to perform an extraction is generally okay. Using “wet” ether to perform a Grignard reaction is a problem. Condition and purpose must both be considered when determining whether or not the chemical is usable. If it is determined to be unusable, then it must be disposed of!

The one group of chemicals that have a limited shelf life, whose age should be tracked very carefully, is the peroxide forming chemicals. It is common practice to check for peroxide formation in this group of chemicals at least every 6 months (even those with stabilizers). The MSDS for a chemical can be consulted for stability information. The more obvious and well known peroxide formers like diethyl ether will have a note about possible peroxide formation. Less common peroxide formers like isopropanol may not have the information listed in the MSDS. Know the structures of the chemicals you are storing and determine whether or not the chemicals fall into this category. One of the best references with regard to peroxide formers is *Bretherick's Handbook of Reactive Chemical Hazards*, where generic structures, as well as specific references to peroxidisable compounds can be found. Basic information can be found on [pages 54-56](#) in *Prudent Practices in the Laboratory*, as well as at the [University of Kentucky's EHS website](#), [University of California, Davis' EHS website](#), or the [CDC's internal Chemical Storage Guidelines](#).

If the chemical appears to be in good condition at its annual check-up, then this is a perfect time to assess the need for keeping this chemical in stock. Will you be using it within the next year? Two years? Five years? If not, take it out of your usable inventory and start the disposal process. Regulatory compliance needs to be considered here, as the EPA may consider older chemicals to be “inherently waste-like” if the chemicals appear not to have been used in some time. I have heard and seen the general rule of thumb on chemical storage to be, if the chemical is not anticipated to be used within the next two to five years, then dispose of it. Your employer may have established procedures with regards to time limits for storage and use of particular chemicals that are more or less stringent than these recommended guidelines.

The last step to keeping the chemicals safely stored is to limit access to chemical stockrooms. Having all chemicals in lockable cabinets would be nice, but this is a financial and logistical problem for many. At the very least, stockrooms should have separate keys which are issued to only those who require access and have proper chemical safety training. Policies with regard to access and disciplinary actions for those who violate the policies should be written up (the Chemical Hygiene Plan would be a good place to have these policies). The world is a different place since 9/11 and the government has a much greater concern about what chemicals are where and who has access to them. As an example, the CDC has a list of “[chemical agents](#)” that they would like to trace more closely. A globally smaller concern is the curiosity of an untrained student who may decide to try a little chemistry experiment at home with some materials taken from your stockroom.

Conclusions

1. Chemicals have life cycles analogous to any living thing. They are born, we acquire them, they require proper shelter/environment, they work, and ultimately they serve a full life and get used up, or they become tainted due to lack of attention or poor management. With this paper, I have suggested what I believe to be safe, ethical and “prudent” ways to acquire and shelter your chemicals. Others will give you guidelines on how they work and ultimately, whether the chemical had a full life or was cut short by “contamination”, how to deal with the disposal issue. Does a chemical get buried, cremated, recycled? I’ll leave that issue for another paper!
2. I would like to stress the point that even though this paper made suggestions with regard to chemical storage in a laboratory/employer setting, all of these suggestions apply to the chemicals you have in your home, too. The regulatory agencies aren’t there to enforce their regulations in the home, but you should think about safety when storing your household chemicals. Are they being stored in such a way that they are compatible with their neighbors on the shelf? Are they compatible with the shelf/cabinet and fixtures around them? Are you using stable, anchored shelving to store your chemicals? Does the temperature in your garage ever exceed the flash point of the chemicals you are storing there? Are you securing chemicals in such a way that children and animals cannot access them? Are you securing chemicals in such a way that they will not easily escape into the environment? Proper handling and storage of chemicals should be a way of thinking at both work and home.

The mention of specific companies and commercial products in this paper are not commercial endorsements for these companies or products.

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