Designing, Building and Using a Home Laboratory
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Part 1. Introduction

In today's world with its terrorism, seemingly rampant drug use and other scary goings on it is certainly not unusual for the idea of building and using a home laboratory to be looked upon, by some, as an activity that must be very suspicious. There will be a never-ending stream of unwarranted remarks from friends and neighbors if you tell them you have a home laboratory. Usually, you'll hear some smart-alecky person ask, "So, you makin' meth?" On the other hand, if you tell someone that you have a workshop in your home, they'll either be very interested and want to talk about their own workshop and what projects you're working on, or they'll be so intimidated by your presumed skills that they'll quickly change the subject. A workshop <u>is</u> a laboratory; a laboratory <u>is</u> a workshop.

My personal travel into life with a home laboratory started when I was 12. Many of my customers at our science store in Parkville know my story well. I received an aquarium and a chemistry set for Christmas. As I like say, aquariums and chemistry have been inextricably linked, in my life, ever since. That link started in 1959 for me; I'd would have liked it to have started earlier, and I now tell our customers that 9 years old for a child, girl or boy, is the nearly perfect age to build and start using a home science laboratory. My father was a cabinet maker, and I never wanted for really nice workspaces with custom built desks and shelving. My first serious laboratory was in our home on Russell Road in Kansas City, It was in the basement, against a wall. My dad's cabinet workshop was on the other side of the basement. If I needed a test tube rack I simply crossed over to his side of the basement and working with a band saw, drill press, glue, clamps and table sander built what I needed. Even though my dad took little interest in what I did in my lab, he was always concerned about my safety, and was ready to assist me when his particular skills were needed.

In our science store we see families with interests in science, and we definitely see families in which the parents want to support their children's interest in science. We don't always recommend a home laboratory, but we are quick to recognize an on-going theme when a family as made a few visits. In those cases we will often recommend a home laboratory as a way for the family to have a shared interest and as a way for the young scientists to understand that they can do real science at home.

Of course, we often see baby boomers like ourselves, my wife and me, who either once had a chemistry set, or a modest home lab, but long since had "out grown" these earlier interests. Many say, "Wow, I wish there had been a store like yours when I was growing up." I think there are very few endeavors in life more interesting and exciting than science…any science. I became a scientist, a chemist, because of my early interest and encouragement. Today I am a chemist as well as an ichthyologist, and my family opened our science store just so there is not another generation that will grow up in Kansas City someday wishing there had been a store like H.M.S. Beagle when they were growing up.

A year or two before we opened the H.M.S. Beagle in Parkville I had designed and built chemistry sets that were housed in large, hardwood cases complete with brass hardware and secret compartments. No two sets were alike; the first one was built as a Christmas gift for a nephew in Hickory, North Carolina. It weighted right at 80 pounds and came complete with over 85 different chemicals. It also had a CD-ROM of the 1936 edition of the A.C. Gilbert *Chemistry for Boys* which accompanied their largest and most complete chemistry sets at the time. That manual is still to be found, in Adobe Acrobat PDF format, on a CD-ROM in the chemistry sets we sell at the Beagle. These sets were constructed of oak or walnut and had contrasting, rare, hardwood inlay accents. Most were built as double cases that were hinged along one long side and opened like a book. The last set I built before opening the Beagle was a triptych (one large case with two smaller ones that closed over it from each side). It was constructed of Osage orange wood and red heartwood. That last kit was sold to Brookside Toy and Science in Kansas City who then resold it. In November 2006 I met the man who bought the set; he told me that he displays it as a piece or art and never uses it! That was never my intention. A laboratory, whether it is nothing more than a shoebox with some modest pieces of equipment, a full-blown chemistry set in a hand-crafted case, or an entire room set up with work benches, cabinets, sinks and more; it is supposed to be used!

So, with this introduction, embark with me on a shared adventure to design, build and use your home laboratory.

Part 2. Location, Location, Location

Just like in real estate where your lab is located is as important as what goes into it. Since the Beagle has been open I have heard nearly everything. “We’ve converted her walk-in closet to a lab space where she can work with her microscope and slides.” “The boys bring the chemistry set into the kitchen and we work with it on the counter.” “I finally got permission from my parents to clear a space in our basement where I have set up a work bench near a sink and where I have access to both electricity and a natural gas connection.”

Probably 90% of beginners will use the kitchen as their home laboratory, at least for a while. The obvious advantages to a kitchen location are access to both hot and cold running water, a sink for cleaning, rinsing and disposing, and ready access to glasses and jars and spoons for measuring and mixing. The problem with the kitchen will eventually become obvious. For one thing one can’t simply leave experiments sitting around and sometime the curious uninitiated (e.g. siblings) may accidentally disturb a critical experiment. Sooner or later, the kitchen is abandoned and a more suitable location will be needed.

I recommend a garage or basement for locating a home laboratory. My first lab started off in a corner of a large basement. My father’s cabinet shop took up most of the basement space (which was really a basement garage), but with a suitable table, close access to running water (there was an extra faucet next to the ones that fed the clothes washer) and a floor drain (down which finished experiments were sent) I was set for my first couple of years.

The Ideal Home Laboratory Space

The ideal space for a very usable home laboratory would be roughly 8’ x 12’ in one corner of a garage or basement. Instead of an assemblage of odd tables and shelves I recommend installing prefabricated upper and lower cabinets like those one can purchase from Lowe's or Home Depot. The base cabinet would have a deep, utility sink with hot and cold water. There would be plenty of electrical outlets and if natural gas was unavailable there should be a propane tank like the ones used for home grills. If natural gas is available one should install a suitable gas valve with a hose barb for attaching flexible tubing. The gas (natural or propane) is used for Bunsen burner(s) and/or for a small hand torch, which when coupled with compressed oxygen could be used for glass blowing. One or two large metal, storage cabinets purchased from a n office supply will work well for the storage of chemicals. If the metal cabinets can be locked this is even better. Between the counter top and the bottom of the upper cabinets a single shelf that runs nearly the length of the cabinet should be installed. This self should be no more than 8" deep (front to back) and should be well supported with metal angle brackets screwed into the wall studs. This shelf is for storing most of the liquid chemicals used in the lab. Under the sink one can store most of the large bottles of liquid chemicals. If possible the lab should be separated from rest of the garage or basement and if possible should have a lockable door. Finally, there should be an easily accessible fire extinguisher inside the lab and another outside the lab. I prefer CO_2 extinguishers, but dry powder types will also work well even though if ever used one will have to clean up a lot of white powder.

3. The work Space

The work space should, if at all possible, be a sturdy table with a top made of a durable surface. Such a surface can be as simple as 5/8" (or thicker) plywood that has been finished with a good quality industrial paint (preferably and "oil based" paint), that readily resists water. The best paint for a lab top is a two-part epoxy (e.g. Tnemec brand, North Kansas City, MO); this will help the surface not only resist water and most dilute acids and alkalis, but also many of the common solvents such as alcohols and ketones (e.g. acetone). If it can be afforded a very good lab bench surface is one of the many composite surfaces (e.g. Corion). These are better than a laminate surface such as Formica since they can actually be sanded with fine sandpaper if they become badly stained or scratched. White is the best surface color since it makes it easier to see spilled chemicals. The surface must be perfectly flat and level; spilled liquids should not run off the surface.

The top should measure at least 24" deep (front to back) and no more than 30"; Making it too deep means that one must reach a long distance across the surface to retrieve items near the back of the top. The length can be any measurement that makes best use of the space available. A five- to six-foot top length should be considered a minimum length. Much shorter and one will find that there is not enough room to spread out projects and experiments. The top's surface area is in addition to the area taken up by the sink (if you have or can install one).

If a sink is installed it should be near one end of the top and not in the center where it can get in the way of the needed work space. Glassware and other equipment that needs to be cleaned in the sink can be placed in the sink until such time that it can be cleaned. In addition, the wall immediately behind or beside the sink should be used for a drying rack of some type. Otherwise, one will need to set aside space on the work top for draining and drying cleaned equipment.

4. Working with Hazardous Materials

No matter what kind of workshop (laboratory) space or set-up one has, it will be difficult to avoid working with hazardous materials at some point. My first exposure to hazardous materials (if one ignores the ever present cigarettes my father smoked) in a workshop were the various paints, varnishes, lacquers, shellacs, and their thinners (VM&P naphtha, mineral spirits, acetone, lacquer thinner, xylol and denatured alcohol) my father used. One could always tell from the odors when my dad was finishing a cabinet or a piece of furniture in the basement or garage.

Many of these same hazardous materials are found in nearly every garage and these are in addition to containers of gasoline, charcoal starter fluid and various other petroleum products. Most of us know and understand the hazards of highly flammable liquids. However, just because we think we know the hazards I will insert appropriate warnings and safety tips in the text of this document, and I will compile a series of appendices at the end one can refer to for more information. New appendices will be inserted from time to time and may not necessarily correlate, at the time of their insertion, to any given text in the body of this document until the entire document is completed.

Typical hazardous materials fall into a few recognizable types:

Poisons
Flammable Gases
Flammable Liquids
Flammable Solids
Corrosives Liquids
Corrosive Solids
Explosives

Most laboratory chemicals have label indications of what hazards are associated. Additionally, material data safety sheets (MSDSs) are available from chemical manufacturers, free of charge, that detail everything one will need to know about every chemical. We offer a CD-ROM of selected MSDSs for the chemicals sold by H.M.S. Beagle and most chemicals have their MSDSs available on-line on the Internet. When searching the Internet simply use the following search terms, “msds sugar.” Instead of “sugar” insert the name of the chemical in which you’re interested.

Appendix A.

Cyanide disposal: Waste Cyanide Destruction by Potassium Permanganate

Potassium permanganate ($KMnO_4$) is a well known oxidizing agent and has been reported to react with cyanide ions in alkaline or neutral media according to the following equation:

$$2KMnO_4 + 31CN^- + H_2O = 2MnO_2 + CNO + 2OH^-$$

For each kilogram of cyanide to be oxidized requires 4.05 Kg of $KMnO_4$. To enhance the cyanide oxidation rate, a catalytic amount of a Cu (II) salt has been found to be very effective. While using only $KMnO_4$ as an oxidant cyanide levels did not drop much after 3-4 periods, but it came down to almost zero level after introduction of catalytic amount of copper (II) sulfate pentahydrate, $CuSO_4 \cdot 5H_2O$.

To destroy the waste cyanide in the lab use the amount of oxidants required according to the equations shown below:

$$\text{Amount of } KMnO_4 \text{ (in grams)} = V \times [C] \times (4.05 \times 10^{-3})$$

(where [C] is the cyanide concentration in milligrams/liter (mg/L) and V is the volume in liters)

$$\text{Amount of } CuSO_4 \cdot 5H_2O \text{ (in grams)} = V \times [C] \times (2.5 \times 10^{-4})$$

For example, when we have treated 25L of 100 mg/L cyanide waste with 10g $KMnO_4$ and 0.6g $CuSO_4.5H_20$, a cyanide probe shows more than 99% of the cyanide having disappeared in less than two hours. To ensure complete oxidation of cyanide and metal cyanide complexes, it is better to keep permanganate treated waste cyanide standing overnight prior to discharge it into sewage.