Introduction

In principle, no chemicals used in laboratory physical sciences are completely harmless, and accidents involving chemicals often result in loss of life or limb. Accidents are bound to happen if you are careless, and the next researcher to be killed, blinded, poisoned, or seriously injured for the rest of her/his life could easily be you or your lab mate. The rules listed below are not meant to be complete, but rather were written to serve as sensible guidelines to good laboratory practice. After reading those rules, take a hard look at your lab and your "usual" lab practices. Then use your intelligence and be as paranoid as you can about what could happen. Then take precautions to prevent accidents.

First and Foremost: Always Know What You Are Doing!

Before you work with a chemical, be sure that you know what kinds of hazards it constitutes. You can learn about chemical hazards in *Material Safety Data Sheets* (MSDS)[1]. Your lab must have an MSDS for each chemical your lab uses, and everyone in the lab must know where the MSDS are. Keep your MSDS library up to date. A very useful resource is the European Union's "R- and S-phrases," which detail the nature of special risks attributed to substances you are using. These risks are also often listed on the container. For more information, see CU's Environmental, Health, and Safety website[2].

If you are using a chemical for a reaction, you must know ahead of time how the reaction proceeds:

Does it generate heat?
Is it violent?
Does it produce toxic gases?
Always label chemical containers, EVEN IF THEY JUST CONTAIN WATER!

Material Safety Data Sheets (MSDS) (1)

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Hazardous Wastes

If you work with chemicals of any kind, you are automatically a Hazardous Waste Generator, according to the definition of CU Boulder. This means that you MUST take a Hazardous Waste Generator Training. The training gives you a few good procedures to work with. Be sure and follow these simple rules:

[1] Link to http://en.wikipedia.org/wiki/Material_safety_data_sheet
[2] Link to http://www.colorado.edu/ehs/resources/guidance.html
[3] Link to http://en.wikipedia.org/wiki/Risk_and_Safety_Statements

- Do not flush solvents or other hazardous wastes down any sink.
- If you clean out glassware, use hazardous waste containers for the waste materials (including the solvents).
- Broken glassware or syringes are hazardous waste, even if they are clean. Do not discard them with the regular trash, because janitors might cut themselves!
- Make sure that you store chemicals properly (see Hazardous Waste Generator Training [4].
- Do not store chemical containers on the floor, creating both tripping and chemical hazards.
- Store different classes of chemicals separately, i.e., acids separate from bases, flammables separate from oxidants.
- Keep containers with flammable substances (e.g., solvents, liquid propane, and flammable gases) closed at all times except when you actually use them.
- Any material on the EPA's "Acute Hazard List" [5] should not be brought onto campus without prior written notification to and approval from the JILA Safety Officer and UCB Environmental Health and Safety. Anyone working with or in the vicinity of these materials must have carefully reviewed the relevant MSDS and fully comply with the MSDS guidelines. Empty containers that have held these substances must be triple rinsed with an appropriate solvent and discarded as hazardous waste (including the solvents). If possible, use other substances.

In case of any accident, remember the phrase: Life Safety First

Chemical Emergencies and Spills

Know where the nearest fire-extinguisher, eye-wash fountain, and chemical safety shower are before you use any chemical. Read and understand the Emergency Action Plan (white or orange sheet of paper that should be close to the lab exit and/or phone in each lab).

If a chemical spill occurs, the right response depends on the nature of the spilled substance and on the size of the spill. The MSDS give advice on how to clean large spills, and they tell you what kind of hazards you face. Make sure that the people around you know of a spill (even a minor one), and keep other people from entering the affected area.

- For **very minor spills** (e.g., a few ml of nontoxic and noncorrosive liquid or a few 100 cm3 of gas at a few Torr), clean up the spill, open the windows, get a fan, and blow out the lab. Remember to collect the cleanup material in a hazardous waste container. Don't breathe in the fumes. Hans Green (B128, x27776) maintains supplies for neutralizing small spills of solvents, acids, bases, and mercury. He can render technical assistance if needed. For example, for a small spill of ethylene glycol (a few ml), it is OK to neutralize the spill and collect the waste in a compatible container for hazardous waste.
- **Larger spills** can constitute a true emergency. If you drop a gallon-sized bottle of solvent and it breaks, you must evacuate the lab and alert Randall Holliness (S175, x24020) to contain and clean up the spill. Don't breathe in the fumes from a large chemical spill.
- In case of a **major spill releasing toxic or corrosive fumes (gases),** evacuate the lab immediately and close the lab door behind you. Activate a yellow pull-box on your floor. Evacuate the building (labs and offices), and call 911 from a safe location.

After hours, or if you cannot reach Hans, Dave, or Randall, call Facilities Management (x25522) and describe the problem.

[4] Link to http://www.colorado.edu/ehs/pdf/HWBook2004.pdf
[5] Link to http://www.colorado.edu/ehs/pdf/EPAplist.pdf

Spills on Clothes and Skin

- Your clothing may constitute a hazard if you work with chemicals.
- As a chemical spill will often hit the floor, this hazard starts with your feet and legs. Wearing flip-flops or other open sandals in the lab where you or your lab mate work with chemicals can expose your skin to a chemical spill, which can induce chemical burns (e.g., from acids or bases) or poisoning (from chemicals that can be absorbed through your skin). Always wear closed toed shoes when in a laboratory setting.
- In case of a fire, clothes with a high content of synthetic fabrics can melt and fuse to your skin before you can take them off. Cotton is a better choice.
- No matter what you wear, if you have a chemical spill and get a chemical on your clothes, remove the affected clothes immediately. Don't put them back on, even if a spill appears to have dried, because there may be harmful residues.
- If a chemical has been spilled on your skin, rinse immediately, continuing to rinse for >15 minutes with lots of cold water. If your eyes are affected, use an eye-wash fountain. Follow the instructions in the MSDS.
- Do not hesitate to seek medical help if the MSDS instructs you to do so. Let your lab mates and your PI know what happened.

Protective Barriers

Always use protective equipment if you work with chemicals. The minimum protection would be to wear a lab coat, vinyl or latex gloves, and protective eyewear. Some situations may warrant a plastic face shield in addition to protective eyewear or goggles. Note that glass is not a good protective barrier, because it can shatter in explosions, producing dangerous flying shards. Contact lenses can damage the cornea when chemicals or vapors are trapped behind them. Use prescription goggles or safety glasses instead. In some cases, vinyl or latex gloves offer little protection, especially if you work with organic solvents. If you spill a droplet on a glove, remove the glove immediately and put a new one on. Do not open lab doors or operate computers while wearing gloves from chemical work. You might unwittingly contaminate door knobs and keyboards this way, and other people may come in contact with harmful substances.

Diluting Acids or Bases

If you work with acids or bases, you often need to dilute a concentrated stock. In many cases, this leads to considerable heating. Always put the water into the mixing container first, and then **slowly** add the concentrated acid or base you want to dilute. Otherwise the heat of the hydration reaction can lead to local superheating of the mixture, resulting in an explosive release of superheated material, which can splash acid or base over you.

Remember: "Do what you oughta, add acid to water."

Highly Corrosive Substances

- Etching or thoroughly cleaning glassware or semiconductor surfaces often call for very aggressive treatment, e.g., with hydrofluoric acid, aqua regia, or "piranha" solution. Some of these aggressive substances, especially "piranha" solution, can attack plastics. If you have never worked with such a substance or if your experience has been a few years ago, talk to David Alchenberger (S120, x22389) before you use them. He has good practical advice. In a corrosive-substance spill, vinyl or latex gloves are of little use. Wear thick rubber gloves. If you or anyone in your vicinity works with HF, familiarize yourself with procedures for handling this extremely toxic substance. Tubes of hydrofluoric acid burn cream are in B128 and in B216.
- Dilute concentrated corrosive substances, such as with acids and bases, before disposing of them in a hazardous waste container. When rinsing glassware that contained concentrated corrosive substances:

- use baking soda to neutralize acids (e.g., aqua regia or piranha solution) until they stop fizzing.
- use diluted vinegar to neutralize bases (e.g., concentrated KOH or NaOH solutions).

➢ Many metals will be corroded instantaneously upon contact with acids, generating H_2 gas, resulting in an explosive mixture with air.

Alkali Metals

➢ Many metals and metal compounds are toxic. Alkali metals present an additional danger because of their high reactivity. In particular, many groups in JILA work with alkali metals (Li, Na, K, Rb, and Cs).

➢ You should always wear a face shield and protective goggles, gloves, and a lab coat when working with alkali metals.

➢ Alkali metals react spontaneously and violently with water as well as with short-chained alcohols (e.g. methanol or ethanol), generating H_2 gas (which can lead to explosions) and metal hydroxides (which are strong bases and highly corrosive). Never bring a piece of alkali metal or a part of your apparatus that is contaminated with alkali metals into contact with water or short-chained alcohols. Alkali metals can even react explosively with ambient humidity (even here in Boulder).

➢ Obviously, never try to extinguish an alkali metal fire with water, use the correct type of fire extinguisher!

➢ If you need to clean away alkali metals from equipment parts, use a long-chained alcohol bath (e.g., isopropanol) for a few hours. Remember that the isopropanol has now become a hazardous waste.

Gas Cylinders

➢ Nearly all JILA labs use compressed gases. No matter the substance, gas cylinders are hazardous, because the main valve can be sheared off if they topple and strike a bench, laser table, or apparatus. A gas cylinder with a sheared-off valve is a rocket-propelled projectile that can break through concrete walls. Therefore, gas cylinders must always be secured, i.e., strapped to something like a wall that cannot move if the valve is sheared off.

➢ When you transport gas cylinders, always put on the cylinder's safety cap before you move it, and only use cylinder carts for transportation. Don't "roll" large cylinders on their bottom edge; this is an unstable way of moving gas cylinders.

➢ Always use the proper reducing valves, pump out the gas lines, and check for leaks before opening a container releasing gases or fumes. These safety precautions are especially important if you work with reactive, toxic, or corrosive gases such as NO, NO_2, CO, or H_2S (there are many others!). For some of these (e.g., CO), commercial detectors can be installed in the lab.

➢ Remember that even if the gases in question are nontoxic (e.g., rare gases or N_2), they constitute a hazard, because they can suffocate you. Never leave flowing gases unattended. If the pumps fail (e.g., because of loss of electrical power), there can be a dangerous buildup of pressure in your apparatus.

➢ And, remember to keep flammable gases and oxygen or other oxidizing agents far apart in the lab.

Fumes

Many of the liquids we use at JILA (and sometimes solids, too) have high vapor pressures at room temperature. Inhaling those vapors is often harmful or toxic, and many are flammable. Use a fume hood for work with such substances. Note that the hood will not work properly if the sash is too high up. Fume hoods have marks on the sides indicating the proper position of the sash for operation. Solvent fumes (e.g., diethyl ether) can make highly explosive mixtures with air, so do not leave bottles open. If you use the common fume hood in the X-Wing, please be aware that any storage must be approved by David Alchenberger (S120, x22389) first. <u>All containers you store there (**even for only a few minutes, even if they only contain water**) must be marked with the content and with your name</u>.

Solvents

Many solvents are carcinogenic (e.g., benzene, toluene) or damage the liver (e.g., CCl_4). Many are absorbed through the skin, and many (e.g., methanol, CCl_4) are toxic. Most laser dyes are carcinogenic as well. Take care not to spill these solvents on your hands. In fact, all organic chemicals should be regarded as toxic unless you know otherwise (e.g., from reading the appropriate MSDS).

Radioactive Materials

Some labs work with radioactive substances, especially metals. At JILA, these materials are usually only mildly radioactive, but that does not make them harmless. An example is thoriated tungsten, used for electron gun filaments. Do not grind or sand such materials to avoid generating dust. If you spot-weld thoriated-tungsten filaments, wear a breathing mask to avoid inhalation of dust. Also, take care not to ingest radioactive substances such as thorium. Lungs and other internal organs can be penetrated by alpha radiation, increasing the risk of cancers of the lung, pancreas, and blood. Exposure to thorium internally leads to increased risk of liver disease.

After you have finished reviewing Chemical Safety Module please see Cindy Torres, JILA Reception to complete the chemical-safety quiz in the Quiz Packet.