ORGANIC CHEMISTRY LABORATORY I

CH  337

Winter 2016

PORTLAND STATE UNIVERSITY
Department of Chemistry
CH 337 LAB SCHEDULE:

Notes:
- Experiments begin on the first day of lab. Safety goggles, a lab towel, and carbon copy notebook are needed for the first lab.
- You must read the lab manual and have your notebook completed before coming to the lab.
- Lab reports are due one lab period after the experiment is completed.

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<th>WEEK</th>
<th>EXPERIMENT</th>
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<tr>
<td>1</td>
<td>Check in.</td>
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<td></td>
<td>Exp. 1: Melting Points. <strong>Report 1 Due Week 2</strong></td>
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<td>2</td>
<td>Exp. 2: Recrystallization</td>
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<td><strong>Report 2 Due Week 4</strong></td>
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<td>No labs this week</td>
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<td>Exp 3: Fractional Distillation</td>
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<td><strong>Report 3 Due Week 6</strong></td>
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<td>5</td>
<td>Finish Exp 3: Fractional Distillation with GC</td>
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<td><strong>Report 3 Due Week 6</strong></td>
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<td>6</td>
<td>Exp 4: Isolation of Eugenol</td>
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<td><strong>Report 4 Due Week 7</strong></td>
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<td>Exp 5: Caffeine from Tea</td>
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<td><strong>Report 5 Due Week 8</strong></td>
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<td>8</td>
<td>Exp 6: Cyclohexene from Cyclohexanol</td>
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<td><strong>Report 6 Due Week 9</strong></td>
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<td>9</td>
<td>Exp 7: Cholesterol from Human Gallstones</td>
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<td><strong>Report 7 Due at the final before 8:00 AM.</strong></td>
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<td>Complete Exp 7: Clean up and check out.</td>
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<td><strong>Report 7 Due at the final before 8:00 AM.</strong></td>
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<td>Final</td>
<td>March 16th 8:00-9:30 AM in CLSB 1A001</td>
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**Course Grading**

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<th>Lab Reports 50%</th>
<th>Notebook 10%</th>
<th>Lab Technique 15%</th>
<th>Final Exam 25%</th>
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Lab reports should be typed. Reports must be written according to the guidelines described in "Format for Organic Chemistry Lab Reports" (Lab Manual). Reports are due one lab period after the experiment is completed. If you cannot turn in a report on time due to a medical or family emergency, inform the instructor in advance to arrange an alternative due date. Otherwise, 5 points/day will be deducted for late reports.

Lab Technique will be evaluated by your lab instructor. The evaluation will include general understanding of the lab, ability to work independently, wearing safety goggles, careful use of chemicals, apparatus and instruments, cleaning up your bench and spilled chemicals, etc.

Notebooks will also be evaluated by your lab instructor. Your pre-lab (worth 10% of your lab write up) is showing the TAs that you have your notebook ready for the lab. The TAs will go around and check your notebook during the lab. If you are caught using a printed manual in the lab you will receive no credit for the lab and will be excused from the lab until the pre-lab is completed. Please don't bring the printout of the experiment to the lab. We will have a computer that has the procedures on it in case you transcribe some information incorrectly. You will turn in the carbon copies of your notebook with your lab report.

**Final Exam** All students take the final at the same time. The final is designed to test your understanding of what you have been doing in lab. The final will focus on the lab operations and chemical reactions directly related to those encountered in the lab. The following comments may assist you in preparing for the final, but they are not intended to be all-inclusive.

For each experiment that introduced a new technique be sure to review what you did, why you did it, the questions that were part of the lab report, the equipment you used, and the basic principles of how and why it works. For experiments that involved chemical synthesis, be sure that you understand such things as the chemical reaction, the basic three-part organization of most syntheses as explained in the lab manual, and the function of the various chemicals, solvents, etc.

Again, review the questions that were part of the report.

***This course has a minimal requirement of 50% on the final exam in order to receive a grade above C. No exceptions will be made.***

There will be NO makeup final exam.

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<td>A</td>
<td>100-85</td>
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<td>B-</td>
<td>71-70</td>
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3
Late Work: Laboratory reports are due at the beginning of the lab period following completion of the experiment. Lab reports should be typed. Late reports will be docked 5 points per day late. After reports have been graded and return you will receive a 0 on reports not turned in.

Attendance: Attendance in this lab is mandatory. YOU MUST ATTEND ALL SCHEDULED LABORATORY SESSION. If you must miss a lab you must notify your laboratory instructor to have an approved or legitimate absence as soon as possible. Students will be responsible for completing the lab report for the missed lab. Data can be obtained from a lab partner or the lab TA. The made up work should be clearly labeled and indicate the origin of the data reported. Reports are due the class meeting following the syllabus deadline. If you miss two or more labs your grade will be a NO PASS.

NOTE: If you are more than 15 minutes late to lab you will be marked absent and not be permitted to complete the lab, two late labs will result in a NO PASS.

Incomplete grades are rarely given in laboratory courses where registration is required to reserve a space to work. If you have an extreme medical or family emergency and cannot complete this course, contact the professor in charge of this course (not your TA) to discuss alternatives.

**Materials**
You will need the following items for this lab:

**Safety goggles** This department requires a type of safety goggles that shield the eyes from all sides and has no vents. They are available at the PSU bookstore or from the chemistry stockroom.

**Notebook** A bound carbon copy notebook with numbered pages is required. You must write in ink in your notebook.

**Lab towel** The lab towel is used to minimize our dependence on paper towels in the lab. You may purchase a lab towel or bring in an old kitchen towel (approximately 24 by 14 inches) to use. No beach or bathroom towels. Anticipate this towel will be thrown away at the end of the year.

**Lab organization**

**Laboratory Clean-Up** It is everyone's responsibility to maintain a safe and organized working space in the lab. You are responsible for the proper disposal of waste chemicals, keeping the balance areas and the instruments free of chemicals and spill, and making sure that your bench is clean before you leave. It is part of your Lab Technique to be evaluated by your instructor.

**Working in Other Lab Sections** If you need to work in a lab period other than your own, first check with the instructor in the lab you want to work in to be sure that there is room. If there is room, fill out a check-out slip for your key, have the instructor initial it, and obtain your drawer key from the stockroom. Return the key to the stockroom when you leave the lab. You should have the instructor sign your notebook after you finish the lab. Your report will not be graded unless it is signed by the lab instructor.

**Glassware Breakage** It is your responsibility to pay for any broken glassware.
Fines for Late Turn-Ins Occasionally you will need to check out specialized equipment not available in your drawer. This equipment must be returned at the end of the period for other lab sections. To encourage prompt return of these items, the stockroom has established a system of fines if they are turned in late. Fines are posted in the lab. If you do not check out of your locker before the end of the term deadline a $50 fee will be charged to your student account.
LABORATORY SAFETY RULES AND PROCEDURES

The most important aspect of the organic chemistry laboratory experience is your safety.

Frequently I get asked “what is the most dangerous thing in an undergraduate teaching laboratory?”. The easy answer is: the undergraduate. Most accidents occur due to neglecting the procedure or messing around in the lab. Accidents will happen, but by following the procedure and using a little common sense your risk of accidents will be diminished.

You will automatically fail the lab if you endanger your classmates, your teaching assistant, or yourself by acting irresponsibly in the lab.

Safety Rules

The guidelines below are established for your and your classmates’ personal safety.

- Personal Protective Equipment (PPE) is used to protect you from serious injuries or illnesses resulting from contact with chemical hazards in the laboratory. Spills and other accidents can occur when least expected. For this reason, it is necessary to wear proper PPE. The PPE for student labs consist of goggles, gloves, and clothing. Proper PPE is required for all students or they will be asked to leave the lab.

- Goggles – The number one rule of the lab is to wear your splash proof goggles at all times. Only indirect-vented goggles are allowed in the student labs and must be worn at all times when any chemical is being used in the lab. Instinctively we feel that it is OK to remove our goggles when we are not directly working with a reaction or reagents. However, you cannot control your neighbor’s or lab mates’ experiments. If your neighbor’s experiment goes awry, you can be hurt.

You should not wear contact lenses in a chemical laboratory. Chemical vapors may become trapped behind the lenses and cause eye damage. Some chemicals may dissolve “soft” contact lenses. The most important aspect of having the goggles fit comfortably is the proper adjustment of the strap length. Adjust the strap length so that the goggles fit comfortably, securely, and are not too tight. If you find that your goggles tend to fog you can obtain anti-fog tissues from the stockroom.
Please read this passage written by
Professor K. Barry Sharpless (2001 Chemistry Nobel Laureate)

Many of you may know that I was blinded in one eye during a lab accident in 1970, shortly after I arrived at MIT as an assistant professor. I always wore glasses whenever I was at my bench, and while I felt I conscientiously observed safety measures, my experience proves one can’t be too cautious about wearing safety glasses.

As I prepared to go home from the lab during the early hours of the morning of the accident, I looked in the bays to see what my co-workers were doing, and then returned to my own bench, removed my safety glasses, and put on my parka. As I was walking to the door, I passed the bench where a first-year graduate student was flame-sealing an NMR tube. I asked how it was going, and he replied, "Good, I've got it sealed."

He was sealing off the tube at atmospheric pressure under a flow of nitrogen gas while cooling the tube in a liquid nitrogen bath, a technique neither of us had performed before. Nor, I regret to say, had we looked up the procedure, which we subsequently discovered to be incorrect.

I stopped by his bench, picked up the tube from the bath, and held it to the light. The tube immediately frosted over, and, as I wiped it to better see the contents, I noticed that the solvent level was exceedingly high. Suddenly the solvent level dropped several inches. Though I instantly realized condensed oxygen had been sealed in the NMR tube, I was quite literally unable to move a muscle before it exploded. Glass fragments shredded my cornea, penetrated the iris, and cause the partial collapse of one eye. My only other injuries were superficial face cuts.

My first two weeks at Mass Eye & Ear were spent totally immobilized and with both eyes bandaged. The pain was terrific, but my fear was even greater: I had been warned that when my eyes were uncovered there was a small chance I might blind in both eyes due to "sympathetic ophthalmia." Because eyes are walled off from the rest of the body in utero, eye protein driven into the blood stream can raise an immune response that leads to the "killing" of the uninjured eye. My disappointment at having no functional vision in my injured eye was, needless to say, surpassed by my joy at retaining full vision in my good eye.

The lesson to be learned from my experience is straightforward: there’s simply never an adequate excuse for not wearing safety glasses in the laboratory at all times.

• Gloves – Gloves should be worn to protect your hands from chemicals. Gloves are located in the student labs and are free of cost. For health and safety reasons, it is important to always remove at least one glove when leaving the student laboratory, in order to prevents things such as door handles from getting contaminated.

• Clothing – Dress appropriately for laboratory work. You must wear shoes that cover your entire foot, including the heel. They should fit up near your ankle. Leather is preferred, but any non-porous material is okay. Your clothing must cover your torso and legs, down to your knees. Short shorts, short skirts, tank tops and halter tops are not allowed.

• Eating, drinking and smoking are prohibited in the laboratory at ALL times. Wash your hands after finishing lab work and refrain from quick trips to the hall to drink or eat during lab. If you take a break, be certain to remove your gloves and wash your hands before ingesting food or drink.

• Never work alone in the laboratory or in the absence of the instructor.
• Headphones and cell phones may not be used in the lab. If you need to use your cell phone, please step out of the lab.

• If you are suspected of being under the influence of alcohol or drugs (legal or illegal) you will be removed from the lab. You will not be able to make up this lab or any point value associated with the lab. If necessary, you will be excused from all future labs and fail the course.

• If you are “screwing around” in the lab in a manner that jeopardizes the safety of anyone in the lab you will be removed from the lab and fail the course.

Safety procedures and procedures if an accident occurs

The number one rule of the lab is to use common sense!

• Know the location of the following safety equipment, fire extinguisher, fire blanket, first aid kit, safety shower, eyewash fountain and all exits.

Fires:

Avoiding fires Most fires occur due to individuals not using common sense. Before lighting a match or burner be sure the area is clear of flammable solids and liquids. As most organic compounds are flammable do not use an open flame around organic compounds. It is especially important to keep all open flames or potential static discharge sources away from highly flammable organic solvents. The vapors from most organic solvents are heavier than air and tend to “sink” to the bottom of a hood or lab bench. Even though you feel you are far away from the solvents you still run the risk of a potential fire.

If organic solvents are spilled on the bench top or in the hood clean them up with a paper towel. Place the soaked towels in a hood (not currently in use for anything else) to dry. Never dispose of solvents in the waste bin or down the sink.

Never pour organic solvents around a hot plate or heating mantle in use, as the vapors may catch on fire.

Extinguishing a fire and burns If a small fire occurs ask your lab mates to clear the area, notify the instructor, and attempt to extinguish it. Small fires may be extinguished by using wet towels or by smothering the fire with a watch glass or beaker. If you feel that you are not in control of a fire please ask for help.

If a larger fire occurs in the hood, shut the sash, calmly tell your classmates to clear the room, and inform the teaching assistant that they will need to use a fire extinguisher. Never try to use water to put out an organic solvent fire.
Fire extinguishers come in classes A-D and K. Our laboratories are equipped with A-C fire extinguishers. Please make sure you know exactly where they are located in the room.

If an individual’s clothing catches fire, walk the individual to the safety shower or roll them in a fire blanket to extinguish the flames. Please report any burns to the instructor. If a severe burn occurs seek immediate medical attention and treat the individual for shock. Have the burned individual lay down in a safe spot, keep them calm, warm, and elevate their feet.

For small heat burns hold the burn under cold water for 5-10 minutes. Please report all burns to the teaching assistants.

**Handling chemicals in the lab:** Before handling any chemical in the lab you should know the risks and safety precautions associated with the chemical. A quick way to look up the safety information for a chemical is by using the chemical’s Material Safety Data Sheet (MSDS). The MSDS can be downloaded from [www.msdss.com](http://www.msdss.com) free of charge.

In case of a small chemical spill on the body or clothing remove the contaminated clothing and wash the affected area with copious amounts cold water and soap. For a large chemical spill stand under the safety shower and flood the affected area with water. Remove clothing to minimize contamination with the chemical. Be sure to report any chemical spills to your TA.

*Spilled chemicals must be cleaned up immediately.* If the material is corrosive or flammable, ask the instructor for assistance. If acids or bases are spilled on the floor or bench neutralize with sodium bicarbonate then dilute with water. Most other chemicals can be sponged off with water.

*If a mercury thermometer is broken, do not attempt to clean up yourself.* Notify students around you then notify your lab instructor or stockroom personnel. The stockroom is equipped for proper clean up and disposal of mercury.

**Spilled Acids and Bases:** If you spill a strong acid on your skin, you will know it right away as the affected area will have a burning sensation. If you spill a strong base on your skin, your skin will feel slippery, as the base is “chewing up” your skin. As stated before, remove any contaminated clothing and wash the affected area with copious amounts of cold water and soap, and report the spill to you teaching assistant.

**Chemicals in the Eyes:** If a chemical does splash into your eyes wash your eyes out for 15 minutes at the eyewash station. This can be a difficult as you will want to close your eye lids as the cold water touches your eye. You will want to hold your eyes open and let the water run over your affected eye/s. After the eye/s has been thoroughly flushed, seek medical treatement. If any corrosive (hydroxide) material comes into contact with your eyes you MUST wash and seek medical attention.
**Inhalation of Organic Fumes:** If an individual inhales a large amount of organic fumes, move the individual to an area with fresh air. You may want the person to sit down if they feel dizzy. If the individual stops breathing, call campus safety (503-725-4404) and ask for 911.

**Cuts:** Minor cuts from broken glass or chipped glassware are common in the lab. If you notice your glassware is sharp please exchange it in the stockroom. For small cuts rinse the cut under cold water to remove any chemicals or fragments of broken glass and apply a pressure bandage to stop the bleeding. For large cuts or strong bleeding cuts apply a large (towel) pressure bandage and call campus safety (503-725-4404) for medical attention.

- *Avoid contact with blood or bodily fluids.* Notify the instructor or stockroom personnel if ANY blood is spilled in the lab so that proper cleanup and disposal procedures may be followed.

**Evacuation:** If evacuation of the lab is necessary, leave through any door that is safe or not obstructed- doors that lead to other labs may be the best choice. Leave the building by the nearest exit and meet your TA on the field next to Hoffmann Hall. This would also be the meeting place in the event of an earthquake or other emergency. It is good to know the nearest exits of your lab on the first day of class.
Laboratory Procedures and Protocol

General Etiquette:

- Leave all equipment and work areas as you would wish to find them.

- Keep your lab bench area neat and free of spilled chemicals. Your book bag, coat, and all other personal items should be kept in the designated area at the entrance to the lab, not at your bench.

- All chemical waste must be disposed of in proper containers. Proper disposal of chemicals is important student safety- putting chemicals into the wrong containers can lead to injury from unexpected chemical reactions. Mixing waste also makes it more difficult and expensive for PSU to dispose of. Waste jars for each experiment will be provided in the lab. They will be clearly labeled specifying which contents should be placed inside. It is important that you replace the lids to the waste containers. Do not put anything down the sink unless you are explicitly told to dispose of it this way. Your instructor will provide specific disposal guidelines when needed. Following these guidelines assists us in lowering the environmental impact of the labs and ensuring your safety.

There are several locations for very specific waste:

- **Chemical waste** – these containers are ONLY for chemical waste generated in the lab. They are each specifically labeled for each lab and waste type. PLEASE READ THE LABELS CAREFULLY.

- **Contaminated paper waste** – is ONLY for paper towels used for cleanup of chemical spills.

- **Broken glass** – is ONLY for broken glassware.

- **Gloves** – is ONLY for used gloves.

- Clean your bench and equipment. Clean all your glassware- dirty glassware is harder to clean later! Wash with water and detergent, scrubbing with a brush as necessary. Rinse well with water. The water and gas should be turned off and your equipment drawer locked.

- Clean the common areas before you leave the lab. Point deductions for the entire class will be imposed if the instructor or stockroom is not satisfied.

- Return any special equipment to its proper location or the stockroom.
Handling Chemicals

Obtaining reagents:

- Read the label CAREFULLY. Chemicals are organized by experiment in secondary containment bins. Make sure the chemical name and concentration match what is required by the experiment!

- Do not take reagents to your bench.

- Never pick up a bottle by its lid as the lid may not be secure. Pick up bottles by the label. Remember to wear gloves while working with reagents.

- Do not put stoppers/lids from reagents down on the lab bench. They may become contaminated. Be sure that the lids/stoppers are replaced when not in use.

- To minimize cross-contamination do not place your own pipet, dropper, or spatulas into the reagent jar. Pour a small amount into a beaker and measure from that. Please pour conservatively to minimize waste and cost of labs. You can always go back for more.

- Never put any excess reagent back in the reagent jar. Treat it as waste and dispose of it properly, do not risk cross-contaminating the reagent for everyone else.

- When weighing chemicals on the balances, never weigh directly onto the weighing pan. Weigh into a weighing boat or beaker. Any spills on the balances MUST be cleaned up immediately. If you are unclear how to clean a spill, notify your instructor. The balances you are using are precision pieces of equipment and costs up to $4000.

- All chemicals should be treated as potentially hazardous and toxic. Never taste a chemical or solution. When smelling a chemical, gently fan the vapors toward your nose.

- Any chemicals that come in contact with your skin should be immediately washed with soap and copious amounts of water. Please inform the TA.
Laboratory Procedures

- Never pipet any liquid directly by mouth! Use a rubber bulb to draw liquid into the pipet.

- Never weigh hot chemicals or hot glassware.

- When heating a test tube, always use a test tube holder and never point the open end of the test tube toward yourself or another person.

- Handling glass tubing or thermometer: to insert glass tubing into a rubber stopper lubricate the glass tubing with a drop of glycerin, hold the tubing in your hand close to the hole, and keep all glass pieces wrapped in a towel while applying gentle pressure with a twisting motion.

- To prepare a dilute acid solution from concentrated acid, acid should be added slowly to water with continuous stirring. Remember AAA—always add acid. This process is strongly exothermic, and adding water to acid may result in a dangerous, explosive spattering.

- Use the fume hood for all procedures that involve poisonous or objectionable gases or vapors.

- Never use an open flame and flammable liquids at the same time.

Checking Into Organic Laboratory
Notice To All Students in Chemistry Laboratories

Please read the notice that was handed out with the equipment list. It describes your responsibility for the equipment once you check in, and discusses other procedures regarding the lab and stockroom.

Safety Equipment. Note the location of fire extinguishers, safety showers, eye wash fountain, first aid supplies, and sodium bicarbonate (for acid spills).

Keys. After having locked your drawer at the end of the laboratory period, please return your key to the key board.
Checking Your Equipment

Please listen carefully to the TA!!! There are pictures of the glassware and associated items available in the lab to help you identify the equipment.

Check to see that there are no chips, cracks, or other defects on the condenser and on the distilling column (large condenser). This is done by gently tapping the condenser and column on the table top; a grating sound means the condenser or column is broken at the ring seals (the point at which the outer tube joins the inner tube). Visually inspect the ring seals for cracks. Look down the column and check that the tips of the three indentations are not broken and look at indentations through the side of the column.

Check the bottom of the round bottom flasks for "star" cracks and other cracks. Scratches are acceptable. Cracks can be detected as they "glisten" when the equipment is rotated. The tube, (adapter thermo), has a glass and a rubber part. Check the bottoms of beakers, Erlenmeyer flasks, and test tubes for "star" cracks and other cracks (especially where sides join the bottom). Check pouring lips and rims of beakers, flasks, and test tubes for chips. Each sample bottle is to have its own cap. The filter flask should have a piece of heavy wall rubber tubing.

The stopcock of the separatory funnel should turn and the stopper for the top should come out. For some drawers, the same stopper fits the ground glass joints and the separatory funnel; for most drawers there are two stoppers, one larger and one smaller. Separatory funnels with Teflon stopcocks have a white washer next to the glass, a black "O" ring, and a Teflon "nut" on the end of the stopcock. All three parts must be there. Stirring rods should be about 6" or longer. Thermometer should read room temperature; if it doesn't, it is probably broken (check the bulb for a crack). You should have 2 pieces of condenser tubing (thin wall rubber tubing), each at least 18" long.

If you need any equipment replaced, list the items on a pink slip and have the instructor sign the slip. Take the slip to the stockroom. On the equipment list, note any student-induced imperfections in equipment not being replaced. Return the equipment sheet to the instructor.
**Laboratory Notebook**

A laboratory notebook is not a report; it is not intended to be a polished product. It should be a complete record of the successes and failures. The polished report is written later, using information from the notebook.

Think of the lab notebook as the "primary record." All data and observations are recorded directly in the notebook rather than on slips of paper, etc. Take the notebook with you when you weigh compounds, keep it open at your desk and make entries as appropriate.

Do not mix up lab lecture notes with the actual experiment. Put lab lecture notes somewhere else altogether or put them in a clearly marked section at the back of the notebook.

The goal in keeping a lab notebook is to have it complete so that you or somebody else could repeat what you did many years later from the information in the notebook.

Keep a running table of contents at the front of the book.

Please see D2L for an example how to keep a notebook.

**Format for Organic Chemistry Lab Reports**

A good lab report is brief, clear, and complete.

*Introduction*

One of the goals of this course is to learn how to report scientific information, which requires accuracy and attention to details. To some of you it may seem like focusing on minutiae but a sloppy technical report gives the impression (probably correct) that the work was done with equal lack of care. There are accepted ways of writing and presenting data that most scientists follow.

All written reports for the organic laboratory are to follow so-called journal style. This format is based on a typical format of an article in a chemistry research journal, such as the Journal of the American Chemical Society (JACS). In any copy of a journal, you will see some variations on this format, but use exactly this style for your reports. You will probably experience some initial uncertainty regarding the degree of detail that is appropriate. Consult with your lab instructor if necessary.

*General Considerations*

All lab reports must be typed. Chemical structures and equations can be drawn with chemical drawing programs, such as ChemDraw and ChemIntosh. These programs are available on computers in the Chemistry Commons (Room 221, SB1). Although it is highly recommended that you learn to use these programs, you are not required to do so at this point.
Scientific articles and reports are typically written using passive voice and personal pronouns such as "I" or "we" are generally avoided (this creates a greater sense of objectivity). For example, write: "The synthesis was carried out . . ." instead of "I carried out the synthesis . . ."; and "To a 25-mL round-bottle flask was added . . . and . . ." instead of "I added . . . and . . . to 25-mL round-bottle flask."

Journal Format
Your lab reports should include the following sections, in this order. Also include the heading for each section except title and author.

Title
Author
Abstract
Introduction
Experimental Section
Results and Discussion
Conclusions
References

Title
Keep it succinct and descriptive. The title as given in the lab manual is adequate.

Author
Your name and affiliation. For example:

Walter White
CH 337 Laboratory, Section 026
Department of Chemistry
Portland State University, Portland OR

Abstract.
This is a very concise summary of the contents of the article. Although it appears at the beginning of the report write this section last. Tell the story of the experiment in the other sections, then summarize it here. Nothing new should be in the abstract, but all of the important points of the paper should be briefly mentioned. The lengths of abstracts vary in the literature; make yours brief. In general abstracts should state what was done, how it was done, and the important results.

An abstract collects the important findings of a paper so that investigators skimming it can decide if they want to invest further time into reading the rest of the paper. Many abstracts are now entered into computer databases and an important new function of abstracts is to provide keywords for computer searches.

Introduction.
This section provides the setting for the information to be presented, discussing why the experiment was performed and what its intention is. Often the historical background of the experiment is mentioned with a reference to the literature the work is based on. For your report this should be a short section, a few sentences. Avoid extensive theoretical discussions.
Experimental Section.
The Experimental Section is one of the most important segments in a laboratory or research report. It should describe the experimental steps completely enough so that someone with some chemistry experience could run the experiment. Be concise; only give enough detail to duplicate the experiment, not a point-by-point description of every motion you made in the lab.

This section should begin with "Materials and Instruments". Identify the materials used, give chemical names of all compounds, and give the chemical formula of compounds that are new or uncommon. List the instrument used to collect the specific data. For example: "The infrared spectra were recorded on a FTIR spectrometer (Perkin Elmer Model xxx)".

DO NOT copy the entire experimental procedure in the lab manual; instead, summarize each step using your own words. Be sure to indicate any changes you made from the procedure. Describe or draw the apparatus, if it is not standard, or if you have made any changes. For example, "Gas chromatograms were recorded following the standard procedure. 3n (Be sure to list the literature in the References Section of your report.)

Results and Discussion.
In this section you present and interpret your data. Present the numbers that your work generates, such as theoretical yield and percent yield. Use chemical structures, equations, graphs, tables or figures when they will clarify your results. Present the results of any purity analysis, such as a melting point, GC, or IR spectra. Be sure to discuss what your numbers, figures, spectra, and graphs mean. Discuss problems you encountered during the experiment. If a procedure did not work as expected describe what went wrong and discuss what might have caused the unexpected result. You may suggest modifications that might improve purity or yield.

Keep this as concise as you can but include adequate text to lead the reader through the ideas comfortably. Use the accepted format for tables and graphs as described in the later section.

Conclusion
Frequently the conclusions that are arrived at in the course of interpreting the data in the previous section are restated here more concisely. Do not repeat discussion points or include irrelevant materials. Your conclusions should be based on the evidence presented.

References
Include a numbered list of references, in the order in which they appeared in the sections above, where they are cited as superscripts. For example, "It was determined some time ago that some amines,7 thiol anions,8 and biphosphate ions8 stimulate the decomposition of MNNG."

Follow JACS style to cite your references. The following examples illustrate the correct punctuation and format.
For books:
author(s)
title (italics) edition, if appropriate publisher place of publication
year of publication volume, chapter, and/or page, if appropriate

Refer to the following for punctuation:

If a book has an editor instead of an author, this is shown after the title. See for example:

For journals:
author(s)
journal title (italics) year (boldface) volume (italics) pages

See example citation 3 for a journal citation:

Special publications such as in-house lab manuals are problematic. You may reference the PSU lab manual as shown in example citation 4:
(4) *Organic Chemistry Laboratory I, CH 337M*; Department of Chemistry, Portland State University: Portland OR; p 1.
Tables and Graphs.

The table and graph reproduced below have typical, acceptable features.

Tables should 1) be numbered (using Roman numerals), 2) have a brief title and 3) have appropriate column headings. Lower case letters are used as superscripts for any explanatory material shown at the bottom. Numerical superscripts may be given, if appropriate, to refer to items in the list of references.

Table I. Calculated Magnetic and Electronic Parameters for \( \text{Cr}_2(\text{O}_2\text{CR})_4\text{L}_2 \)

<table>
<thead>
<tr>
<th>Compound</th>
<th>( E, \text{ cm}^{-1} ), MHz</th>
<th>( \text{ddia}, \text{ ppm} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. ( R = \text{Me}, L = \text{MeOH}^a )</td>
<td>1004</td>
<td>0.3363</td>
</tr>
<tr>
<td>II. ( R = \text{Me}, L = \text{H}_2\text{O}^b )</td>
<td>980</td>
<td>0.3677</td>
</tr>
<tr>
<td>III. ( R = \text{Me}, L = \text{py}^b )</td>
<td>958</td>
<td>0.3236</td>
</tr>
<tr>
<td>IV. ( R = \text{Me}, L = \text{MeCN}^c )</td>
<td>926</td>
<td>0.3478</td>
</tr>
<tr>
<td>V. ( R = \text{CF}_3, L = \text{Et}_2\text{O}^d )</td>
<td>462</td>
<td>0.1728</td>
</tr>
<tr>
<td>VI. ( R = \text{NEt}_2, L = \text{NHEt}_2^e \text{CH}_3 )</td>
<td>611</td>
<td>0.0106</td>
</tr>
<tr>
<td>VII. ( R = \text{NEt}_2, L = \text{NHEt}_2^e \text{CH}_2 )</td>
<td>578</td>
<td>0.0388</td>
</tr>
</tbody>
</table>

\(^a\text{Recorded in CD}_3\text{OD}: \(^b\text{Recorded in acetone-}\text{d}_6: \(^c\text{Recorded in CD}_3\text{CN}: \(^d\text{Recorded in Et}_2\text{O}: \(^e\text{Recorded in toluene-}\text{d}_8. \)
Graphs should be labeled as a numbered figure (using Arabic numerals) and have a descriptive title. For your graphs, do the following:

1. Use Excel or other drawing program. Hand-drawn graphs are not acceptable.

2. Label the axes, including units.

3. Assign the independent variable (the one you control) to the x axis (horizontal) and the dependent variable (the system’s response) to the y axis (vertical).

4. Select a range of numbers for an axis so that most of the graph paper is used. You don’t necessarily have to start at zero.

5. On each axis, place tic marks at regular intervals.

6. Plot each data point as a point enclosed in a circle.

7. When drawing a curve through the data points, decide on the best fitting smooth curve. Don’t simply connect the points with straight lines. In selecting the best fit curve, you can use your understanding of how the system normally behaves.

Figure 3. Effect of pH on removal of Zn(II) by sol-gel glass resin.