CHE310 LABORATORY SCHEDULE Spring Semester 2005


Other materials: A bound laboratory notebook with numbered pages.
Safety goggles, available for purchase from bookstore.

Lab Times: A Monday 12:40 - 4:40
B Tuesday 2:15 – 6:15
C Thursday 2:15 – 6:15

Grading: The laboratory will be worth 185 out of 775 points for the entire course (or approx. 24%). All of the laboratory must be completed in order to receive a passing grade in the course.

Breakdown of laboratory points.

80 points 10 points for each of the labs, graded in your notebook.
32 points One laboratory quiz for each experiment, except the enzymatic reduction of a ketone. Each worth 4 points. These will be done, through Blackboard. You will have two chances to submit your answers. This must be done before 9:00 am on the day of your lab.
43 points Spectroscopy
15 points - The final project of the semester will utilize NMR spectroscopy. You will be required to run both a proton and carbon NMR on the aldehyde used in your Aldol condensation. I will supply a proton NMR of your final product. You will need both of these to identify your unknown. You should also correlate the protons and carbons in your structure to peaks in the spectrum.
10 points each - Two GC-MS spectra - one for the cyclohexanol oxidation, the other for the fatty acid lab. The mass spectra should be interpreted, including an accurate structure for the molecular ion, and accurate structures for at least two fragment ions. Comment on any impurities visible in the chromatogram that have resulted from your synthesis. These should be turned in at the same time your notebooks are due for these same experiments.
4 points each - Two IR's taken on any products that you make and isolate. In each of these you should label at least three vibrational bands that represent the functional groups in your molecule. These should be turned in with your notebook.
10 points  Technique - 10 points.  Throughout the semester, your laboratory instructor will take note of how carefully and independently you work in the lab. Everyone starts with full credit. Points are taken away from that starting point.

20 points  Lab Final - this will be a written exam given on the last day of laboratory. It will not cover specifics from any lab, but rather will be over the techniques we have used throughout this year.

Preparation:  Your notebook must be prepared in advance of each lab. You are required to read the laboratory details as well as the reference techniques for each experiment before coming to laboratory. We will take only a few minutes at the beginning of each lab to go over any final questions you may have. The better prepared you are, the better the experiments go.

<table>
<thead>
<tr>
<th>DATE</th>
<th>LABORATORY</th>
<th>DETAILS</th>
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<tbody>
<tr>
<td>Jan. 31, Feb. 1,3</td>
<td>Introduction and Check-in</td>
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<tr>
<td>Feb. 7,8,10</td>
<td>Handout: Iodination of Vanillin</td>
<td>Work individually</td>
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<td><strong>Notebook Due: Friday Feb. 18</strong></td>
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<tr>
<td>Feb. 14,15,17</td>
<td>Handout: Synthesis of Porphyrin</td>
<td>Work in pairs</td>
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<td><strong>Notebook Due: Friday Feb. 18</strong></td>
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<tr>
<td>Feb. 21,22,24</td>
<td>Experiment 13: Oxidation of Cyclohexanol</td>
<td>Work in pairs</td>
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<td>(Miniscale - Run reaction 1/2 scale)</td>
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<td><strong>Notebook Due: March 18 – but don’t put off getting the work done until then!</strong></td>
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<tr>
<td>Feb. 28, March 1,3</td>
<td>Experiment 13: GC-MS analysis of product</td>
<td>Work in pairs</td>
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<td>Spectroscopy Sessions</td>
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<td>March 14,15,17</td>
<td>Handout: Combinatorial Chemistry</td>
<td>Work in pairs</td>
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<td><strong>Notebook Due: March 24</strong></td>
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<td>Handout: Analysis of fatty acids in oils</td>
<td>Work in pairs</td>
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<td><strong>Notebook Due: April 1</strong></td>
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<tr>
<td>March 21,22,24</td>
<td>Experiment 12.1 - Synthesis of Esters</td>
<td>Work individually</td>
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<td>(Miniscale - Run reaction 1/2 scale)</td>
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<td><strong>Notebook Due: April 1</strong></td>
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<td>GC-MS analysis of fatty acids</td>
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<td>March 29,31 April 4</td>
<td>Experiment 28.2 - Synthesis of DEET</td>
<td>Work in pairs</td>
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<td>April 5,7,11</td>
<td>Project 11 – Aldol Condensation with unknown ketones and aldehydes</td>
<td>Work in pairs</td>
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<td>April 12,14,18</td>
<td>Project 11 - continued</td>
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<td>April 19 and 21</td>
<td>Lab open for spectroscopy sessions</td>
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<td>April 25,26 and 28</td>
<td>Spectroscopy sessions Laboratory Check-out</td>
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<td><strong>Laboratory Final</strong></td>
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Experiment Specifics

Iodination of Vanillin

Recrystallization – Technique 9.1, 9.5-9.6, pg. 78-81, 83-88
Melting Point Determination - Technique 10.2-10.4, pg. 96-102

This experiment is an example of an electrophilic aromatic substitution. The green lesson to be learned here is that sometimes reactions can be run in water as a solvent, producing less waste, and being much safer than using organic solvents. We are also obtaining iodine from a redox reaction between sodium iodide and sodium hypochlorite, rather than using bromine, or chlorine, which are both more difficult to work with. This reaction will be run individually. We do not have rotary evaporators available for our use. When you come to this point in the procedure, simply chill on ice, and then vacuum filter. Run the recrystallization in ethyl acetate. Your melting point will be better if you dry your product for a week before taking it.

Notebooks due Feb. 18

Synthesis of Porphyrin

Technique 7: Heating Methods, pg. 44 (sand baths)
Technique 15: Thin Layer Chromatography, pg. 153-162
Technique 17: Liquid Chromatography, pg. 178-187

This experiment is another example of an electrophilic aromatic substitution, albeit more complicated than the first. It also involves an oxidation to complete the conjugation of the large ring. Porphyrins are the core structure in molecules such as chlorophyll, and hemoglobin, and thus very important in nature’s electron transfer processes. The green lessons to be learned here are that sometimes a reaction can be run in the absence of solvent, in this case, in the gas phase. Porphyrins have not been traditionally synthesized in this fashion. The oxidative reagent in the second step is simply air. The purification of our product will be done with column chromatography, which is inherently non-green. It produces a large amount of solid waste, and utilizes a large amount of organic solvents. Nevertheless, it is still a standard way of purifying organic compounds in the laboratory.

You will run this reaction with your lab partner. We will be using a sand bath, in one of your small heating mantles, with the heat provided via your variable transformer. Higher temperature mercury thermometers will be supplied for measuring the temperatures. (This is definitely not green!) Be careful with them! As you set up your reaction vial, the Teflon side of the septum should be towards the inside of the vial. You will be using fine syringes to inject your reagents into the vial. Again, treat them gently. Analyze your product mixture with TLC. This time we don’t need to use uv-activated plates, because our products and impurities are colored. Purify your product with column chromatography. We will not be performing the visible spectroscopy. You do not need to calculate a yield.

Notebooks due Feb. 18

Oxidation of Cyclohexanol: Experiment 13

Steam Distillation – Technique 11.7, pg. 129-133
Simple Distillation - Simple Distillation – Technique 11.3 – 11.3a, pg. 109-113
Gas Chromatography – Technique 16.1, pg. 163-175
Mass Spectrometry - Technique 20.1-20.2, pg. 284-289

This experiment is an example of an oxidation, as we have been studying in class. Most of our reactions in class have been done with some form of chromium. This oxidation, however, is done with household bleach, i.e. the green lesson in this experiment. This reaction will be run in pairs, and will be performed over a two week period. It should be run at 1/2 scale. You should run the reaction in a 250 ml round bottom flask, with a Claisen condenser. Put the thermometer in the center inlet, and the addition funnel on the outer neck. We will perform the simple distillation. You will check for the extent of reaction with gas chromatography/mass spectrometry. Comment on the ratio of starting material to product in the
conclusion of your lab. We will also use the library on the instrument to identify the surprising byproducts that result from this oxidation reaction.

**Notebooks due March 18**

**Combinatorial Chemistry**

This experiment demonstrates the formation of an imine, a reaction of carbonyl compounds studied in class. More importantly, it is an example for combinatorial chemistry, a process in which many different compounds are synthesized simultaneously, and tested for biological activity, before individual syntheses are developed. This technique has enabled the pharmaceutical industry to prepare many more compounds than ever in the past. By its very nature it is a green process, because possible targets for a biological activity are screened before elaborate step-wise synthetic and purification methodologies are developed. There are no complicated techniques in this experiment, but you must be careful in your planning, and record keeping. We will be synthesizing 16 compounds today (!) and then testing them for antibiotic activity. You will be required to come in to lab during an additional time to check for growth of bacteria on your agar plates.

**Notebooks due March 24**

**Analysis of fatty acids in oils**

- Extraction – Technique 8.2-8.4, 8.7-8.8, pg. 59-65, 72-75
- Gas Chromatography – Technique 16.1, pg. 163-175

You and your lab partner will identify an oil by first saponifying it, esterifying it with methanol, and then analyzing the product ratios using GC-MS.

**Notebooks Due April 1**

**Synthesis of Esters: Modified Experiment 12**

- Heating Under Reflux -Technique 7.1, pg. 48-50
- Extraction – Technique 8.2-8.4, 8.7-8.8, pg. 59-65, 72-75
- Simple Distillation – Technique 11.3 – 11.3a, pg. 109-113

This reaction will be run individually. We will be synthesizing a variety of esters, all of which are known for their unique, and pleasant odors and often used as flavorants in candies. In order to cut down on reagent use, and generated waste, we will be running the experiment at half-scale. You may choose to use isopentyl alcohol, pentanol, butanol, or hexanol. Do something different than what your hood partner is doing. Use 0.075 moles of your alcohol. You will need to use the density and molecular weight of your alcohol in order to know how many grams, or mls to begin with. All of the other reagent amounts can simply be halved. You should run the reflux in a 50 ml flask. Perform the procedure through the simple distillation. You may run a short path distillation depending on the amount of material you have. Consult your techniques manual – pg. 113. You can expect that your ester will boil between 12 – 16 ° higher than the alcohol you used.

**Notebooks due April 1**

**Synthesis of DEET – Experiment 28.2**

- Removal of Noxious Vapors - Technique 7.4, pg. 52-55
- Extraction – Technique 8.2-8.4, 8.7-8.8, pg. 59-65, 72-75

In your final experiment of the semester, you will synthesize DEET, the ingredient in OFF and other insect repellants, with a partner. We will be using a gas trap for collecting the gas given off. Amines have strong, bad smells so you should be careful to dispense this only in a hood, and keep it capped as you carry it to your work area. We will isolate the final product, but will not purify it with column chromatography.

**Notebook due April 15**
Aldol Condensation with unknown ketones and aldehydes – Project 11
Selecting a Recrystallization Solvent – Technique 9.2, pg. 81-82
Recrystallization – Technique 9.1, 9.5-9.6, pg. 78-81, 83-88
Microscale recrystallization - Technique 9.7, pg. 88-89

In this experiment you will be given two compounds, an aldehyde and a ketone. You will run an aldol condensation on these two. In order to identify the starting materials, and the product, you will do three things. You and your partner will take both a proton, and carbon NMR of the aldehyde. You will prepare the 2,4-dinitrophenylhydrazone of the ketone, crystallize it, and determine its melting point. You will also recrystallize and take the melting point of the final product. I will provide a proton spectrum of your final product. These pieces of data should allow you to determine the structure of your starting materials, and the resulting aldol condensation product. This project will be performed over several weeks.

Notebook due April 29

Spectroscopy

Spectroscopy will be a major portion of your work this semester, as this is an important way to prove the identity of a synthetic product. You will be using the NMR, the IR and a gas chromatograph-mass spectrometer. Here are the requirements for each assignment.

IR, Technique 18 - Take an infrared spectrum of two of your products this semester. Run the first with your lab partner. The second one should be run individually. These spectra should be turned in with your laboratory notebook, and will be graded by the lab assistant. While it would be best to complete the IR work before a lab is due, they can be turned in during later weeks. But do not put it off to the end of the semester!

NMR spectroscopy, Technique 19 - This technique will be used in the last laboratory. You and your lab partner will run both a proton and carbon spectrum of an unknown aldehyde. I will provide an NMR of your aldol condensation product.

GC-MS, Technique 20 -

We will use GC-MS to determine the ratio of alcohol to ketone in the oxidation of cyclohexanol. This experiment is run in pairs. We will also use the data base that comes with the instrument to identify some unusual byproducts that are a result of this oxidation. For two of the compounds you should draw an accurate structure for the molecular ion, as well as two fragment ions. Accurate structures indicate whether the ions are cations, or radical cations, and where the electron might have been removed from. Comment on the ratio of starting material to product in the conclusion of your lab.

GC-MS will also be used to determine the fatty acid components of an oil. Identify all fatty acid components of your mixture. For two of them, draw an accurate structure of the molecular ion, and two of the fragment ions.

These spectra should be turned in separately, but at the same time the notebooks are due for these experiments. The laboratory instructor will grade them.