Harvard University CHEMISTRY S-20ab: Organic Chemistry — Summer 2014

https://canvas.harvard.edu/courses/571

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Head TFs: **Section:** Peter Hamel (hamel@fas.harvard.edu)
Lab: Matthew Patton (mpatton@g.harvard.edu)

COURSE DESCRIPTION: This course is an intensive, comprehensive introduction to the chemistry of carbon and its importance to biological molecules. A good knowledge of general chemistry is ***required***, and thorough familiarity with topics covered in a college-level general chemistry course is ***assumed***. Topics include current ideas of bonding and structure, major reaction mechanisms and pathways, a discussion of the analytical tools used to determine the structure and stereochemistry of organic compounds (such as infrared and NMR spectroscopy), and some of the chemistry of amino acids, peptides, carbohydrates, and nucleic acids. This course fulfills the requirement of two semesters of organic chemistry for entrance to medical school. **Prerequisite:** Two semesters of general chemistry or the equivalent, with grades of B– or better. Students without adequate background may not be able to keep up with the course. Not appropriate for high school students. **Enrollment is limited.**

SCHEDULE: The schedule of section and lab meetings will be determined on the first day of class, as explained below. **We cannot arrange section or lab schedules in advance**. This course is extremely intense (*more than 60 hours per week*) and you are advised not to participate in any other activities for the duration of the course.

BOOKS (available at the Harvard Coop or at FlashPrint as listed below):

Required: Molecular model kit (any one is fine; they sell them at the Coop).
The Organic Chem Lab Survival Manual, James Zubrick (any recent edition is fine; Coop)
Blank laboratory notebook with duplicate pages (Coop)
Chem S-20 Lab Manual available at **FlashPrint**, 99 Mt. Auburn St. in Harvard Square

Recommended: *Organic Chemistry*, G. Marc Loudon, Fifth Edition (available at the Coop)
Organic Chemistry as a Second Language, Vol. I, David R. Klein (Coop)

LECTURES:

Mondays	8:30–11:30am (first week only; subsequent Mondays begin with an exam at **8:10am**.)
Tuesdays	8:30–11:30am
Wednesdays	8:30–10:45am
Thursdays	8:30–10:45am
Fridays	8:30–10:45am

EXAMS:

There will be 6 in-class exams, **every Monday** from June 30–August 4.
Each exam will run from **8:10–9:20am**, and will be followed by lecture from 9:30–11:30.
No make-up hour exams will be given.
There will be a comprehensive **final examination** tentatively scheduled for **Friday, August 8**. As stated in the Summer School Handbook: "All undergraduate- and graduate-credit students must take the final examination in order to earn a credit and a final grade for the course. Any credit student who does not take the examination must be assigned a final grade of ABS (absent)."

DISCUSSION SECTIONS:

Discussion sections meet **every day**; your particular schedule will be determined on the first day of class.

Mondays	11:30am–12:30pm	*or*	1:00–2:30pm
Tuesdays	11:30am–12:30pm	*or*	1:00–2:30pm
Wednesdays	10:45am–12:30pm	*or*	1:00–2:45pm
Thursdays	10:45am–12:30pm	*or*	1:00–2:45pm
Fridays	10:45am–12:30pm	*or*	1:00–2:45pm

WEEKLY REVIEWS: Held every Friday in Sci Ctr C from 3–5pm to help you prepare for Monday exams.

LABORATORIES (in Sci Ctr 210):
On the first day of class, you will be assigned to one of the following lab groups based on your preference:

Group A: Monday 1:00-6:00 PM and Wednesday 6:00-11:00 PM
Group B: Monday 6:00-11:00 PM and Wednesday 1:00-6:00 PM
Group C: Tuesday 1:00-6:00 PM and Thursday 6:00-11:00 PM
Group D: Tuesday 6:00-11:00 PM and Thursday 1:00-6:00 PM

The first labs will meet on Wednesday, June 25 and Thursday, June 26. In subsequent weeks, every student will have labs **twice** each week according to the schedule above. (Note that there will be no labs on Wednesday, July 2 or Thursday, July 3 in preparation for the holiday.**) Attendance at all laboratory sections is required**; students who miss **any** labs will **not receive a passing grade for the course**. There will be **no exceptions**.
A detailed **laboratory syllabus** is included at the end of this document; please read it carefully.

HELP ROOM:

The help room will be staffed by TFs:	Tues, Wed, Thu	3–5pm Sci Ctr B-10
	Sundays	2–6pm Sci Ctr 302

EXAMINATIONS AND GRADING:
Your grade will be based on:

Top 5 Hour Exams	50%
Final Exam	30%
Lab	20%

There will be **no makeup examinations** for the exams; we will drop your lowest exam (or one missed exam).
This course is **not graded on a curve**; we will use the following scale to assign letter grades:

85 – 100	70 – 85	55 – 70	50 – 55	below 50
A– or A	B–, B, or B+	C–, C, or C+	D	F

The cutoffs for the + and – grades are left to our discretion.

REGRADING POLICY: PLEASE READ THIS CAREFULLY! Requests for regrades ***must*** be submitted to the Head Section TF ***in writing***, ***by 3:00 pm on the Friday afternoon following the exam***. **NO EXCEPTIONS** will be made to this deadline. A fully completed regrade request form ***must*** be submitted along with the regrade request – the forms can be downloaded from the course web site. **If you make changes to your exam and submit it for a regrade, we will report you to the Harvard Administrative Board for academic dishonesty. We *will* be photocopying exams before returning them to you**.

CLASSES: Below you will find a list of topics that will be covered in the following weeks. Undoubtedly there will be some changes as we progress, and so regard this as a rough guide only! We will update as necessary. The individual topics below are not equal in length or importance - each 'bullet point' below does *not* represent an equal amount of time. Some will take only a few minutes of class, others much more.

MAKE THE MOST OF CLASSES: You will find classes much more rewarding if you familiarize yourself with the topics *before* we cover them in class. We have indicated the relevant chapters in Loudon, and (more or less) used the same sub-headings as in the text for individual topics below. We will NOT slavishly follow the text - We will spend more time on some topics than others - We will not necessarily follow the same order as the text. We will discuss things that are not in the text. On occasions we will delve deeper into the underlying principles, and look wider into nature for examples of reactions and structures. Nevertheless, if you read the indicated chapters and make notes on the relevant topics before we cover them in class, you will be well prepared to deal with the material.

MOLECULAR MODELS: You will find a set of molecular models invaluable. Once you have tired of making models of dogs, giraffes, etc., you will find the models extremely useful in visualizing molecules in 3D. After the course, you can go back to making animal models... You will be able to purchase an appropriate set from the COOP.

TENTATIVE LECTURE SCHEDULE follows:

Week 1

June 23: Chemical Bonding, Organic Structures, and Alkanes (Chapters 1 and 2)

- Introduction
- Classical theories
- Structures of covalent compounds
- Resonance structures
- Atomic and molecular orbitals
- Hybridization
- Shapes of molecules
- Structural representation of alkanes
- Structural representation of functional groups
- The 'R group' notation
- Naming organic structures (an introductory overview)
- σ-Bonds and related orbitals (σ- and σ*-orbitals)
- Other hydrocarbons (introduction)
- Conformations (ethane and butane)
- *syn*-Pentane interactions (not in Loudon)
- Free energy and equilibria
- Isomers and nomenclature
- Cycloalkanes
- Combustion of alkanes

June 24: Acids, Bases, and Arrows - Writing Organic Mechanisms (Chapter 3)

- Review of important concepts
- Introduction to Frontier Molecular Orbitals
- Lewis acid + Lewis base reactions
- Electron-pair displacement reactions

June 25: More on Frontier Molecular Orbitals (FMO) (not in Loudon) – the 'donor–acceptor' model for describing, understanding, and predicting organic reactions. (*It's much easier than it sounds!*).

- Brønsted–Lowry acids and bases
- pK_a - Acidity and structure
- Resonance structures

Introduction to Alkenes (Chapter 4)

- The C–C double bond
- *Cis-trans* isomers & nomenclature (incl. *E*- and *Z*- formalism)

June 26: Chemistry of Alkenes (Chapters 4 & 5)

- Relative stability of alkene isomers
- Addition reactions
- Carbocations
- Free energy profiles
- Multistep reactions
- Hammond's postulate
- Catalysis - Hydrogenation, hydration, enzymes
- Halogens

June 27: Additions to Alkenes (Chapter 5)

- Halohydrin formation
- Alcohol formation (hydration and hydroboration)
- Ozonolysis
- Glycol formation
- Free radical additions
- Bond dissociation energies

Week 2

June 30: Exam 1

June 30: Stereochemistry (or 'Shape Matters') (Chapter 6)

- Enantiomers and chirality
- Asymmetric carbon and stereocenters
- Chirality and symmetry
- *R,S* Nomenclature
- Optical activity, diastereoisomers, and *meso*-compounds
- Enantiomer resolution
- The importance of being asymmetric

July 1: Cyclic Compounds and Stereochemistry of Reactions (Chapter 7)

- Monocyclic alkanes, cyclohexanes
- Cyclopropane, cyclobutane, cyclopentane
- Bicyclic and polycyclic compounds
- Reactivities of stereoisomers
- Reactions that form stereoisomers
- Reaction stereochemistry - addition and substitution - bromine addition
- Stereochemistry of hydroboration–oxidation and other additions

July 2: Introduction to Alkyl Halides, Alcohols, Ethers, Thiols, and Sulfides (Chapter 8)

- Nomenclature, structures, polarity, hydrogen bonding, and properties
- Solvents
- Acidity of alcohols and thiols; basicity of alcohols and ethers
- Grignard and organolithium reagents
- Industrial preparation and uses

Introduction to Chemistry of Alkyl Halides (Chapter 9)

- Elimination and substitution - An overview
- β-Eliminations

July 3: Chemistry of Alkyl Halides Continued (Chapter 9)

- Nucleophilic substitution
- Reaction rates and activation energy
- S_N2 Reactions
- E2 Reactions
- S_N1 Reactions and E1 Reactions
- Summary
- α-Eliminations
- Alcohol dehydration
- Alkyl halides from alcohols

July 4: *Holiday (Independence Day)*

The usual "Friday Review" will be held on Thursday, July 3 due to the holiday.

Week 3

July 7: Exam 2

July 7: Infrared, Mass, and Nuclear Magnetic Resonance Spectroscopy (Chapters 12 & 13)

- Introduction to spectroscopy
- Infrared spectroscopy
- Infrared absorption and structure (good vibrations)
- Functional group absorptions
- Introduction to mass spectrometry
- Introduction to NMR spectroscopy
- Chemical shift
- Functional group NMR absorptions

July 8: Nuclear Magnetic Resonance Spectroscopy (Chapter 13)

- Spin–spin splitting
- Solving unknown structures
- (slightly more) Complex NMR spectra
- Carbon NMR
- Problem solving with combined spectroscopy

July 9: Chemistry of Alcohols, Glycols, Thiols, Ethers, Epoxides, and Sulfides (Chapters 10 & 11)

- Oxidation and reduction
- Oxidation to aldehydes, ketones, and carboxylic acids
- Group equivalence
- Thiol oxidation
- Williamson synthesis
- Ethers from alkene addition

July 10: Chemistry of Ethers, Epoxides, and Sulfides (Chapter 11)

- Synthesis of epoxides
- Cleavage of ethers
- Nucleophilic substitution of epoxides
- Glycol cleavage
- Sulfonium salts
- Neighbouring–group participation

Alkyne Chemistry and Organic Synthesis (Chapter 14)

- Structure of alkynes
- Acidity of alkynes

July 11: Alkyne Chemistry and Organic Synthesis (Chapter 14)

- Additions to alkynes
- Reduction of alkynes
- Introduction to Organic Synthesis and Synthetic Strategies

Dienes, Allylic, and Benzylic Reactivity (Chapters 15 & 17)

- Allenes (structure and stereochemistry)
- Conjugated dienes (1,3-dienes)
- Resonance & MO representation of conjugated π orbitals
- Addition of hydrogen halides to conjugated dienes
- Spectroscopy of benzene derivatives
- Allylic and benzylic reactivity

Week 4

July 14: Exam 3

July 14: Aromaticity and Electrophilic Aromatic Substitution (Chapters 15 & 16)

- Benzene, aromaticity, and other aromatic systems
- Nomenclature of benzene derivatives
- Other aromatic systems
- Electron donating and withdrawing groups
- Inductive vs. resonance effects; effects of substituents
- General mechanism of electrophilic aromatic substitution
- Halogenation, Nitration, Sulfonation, Friedel-Crafts Alkylation and Acylation

July 15: Electrophilic and Nucleophilic Aromatic Substitution (Chapters 16 & 18)

- Directing and activating effects in electrophilic aromatic substitution
- Use of electrophilic aromatic substitution in synthesis
- Unreactivity of aryl and vinylic halides
- Nucleophilic substitution of aryl halides (benzyne and addition-elimination mechanisms)

Aldehydes and Ketones - Carbonyl Addition (Chapter 19)

- Structure and reactivity of the C=O group
- Irreversible additions to aldehydes and ketones: Grignard reagents, $NaBH_4$, and $LiAlH_4$

July 16: Aldehydes and Ketones - Carbonyl Addition (Chapter 19)

- Reversible addition reactions of aldehydes and ketones: hydration, hemiacetals, acetals
- Use of acetals as protecting groups
- Formation and hydrolysis of imines and enamines
- The Wittig Alkene Synthesis
- Reduction of aldehydes and ketones to alkanes

July 17: Chemistry of Carboxylic Acids and their Derivatives (Chapters 20 & 21)

- Acidity of carboxylic acids
- Preparations of carboxylic acids
- General mechanism for interconversion of carboxylic acid derivatives
- Introduction to the Grid of Carbonyl Love
- Converting between carboxylic acids, acid chlorides, esters, and amides
- Hydrolysis of nitriles

July 18: Chemistry of Carboxylic Acids and their Derivatives (Chapters 20 & 21)

- Reduction of esters, carboxylic acids, amides, and nitriles with $LiAlH_4$
- Alternative methods for the synthesis and hydrolysis of esters
- Relative reactivity of carboxylic acid derivatives
- Reaction of carboxylic acids and derivatives with hydride reagents, Grignard reagents, and organolithium reagents
- Preparation of ketones from carboxylic acids and derivatives
- Reduction of esters to aldehydes (DIBAL)
- Oxidizing ketones: The Baeyer-Villiger Oxidation
- The complete Grid of Carbonyl Love

Week 5

July 21: Exam 4

July 21: Introduction to carbohydrates, peptides, and proteins (Chapters 24 & 26)

- Structure, nomenclature, and stereochemistry of carbohydrates
- Formation of acetals, disaccharides, and polysaccharides
- Structure of alkyl glucosides: the anomeric effect
- Structure and synthesis of amino acids
- The peptide bond and synthesis of peptides
- Solid-phase peptide synthesis

July 22: Enols, Enolates, and α,β-Unsaturated Compounds (Chapter 22)

- Acidity of C=O compounds (enolate formation)
- Tautomerization of C=O compounds (enol formation)
- Deuteration and racemization of α-carbons
- Halogenation under acidic and basic conditions; the haloform reaction
- Indtroduction to the aldol reaction: addition and condensation
- Intramolecular and crossed aldol condensations

July 23: Enols, Enolates, and α,β-Unsaturated Compounds (Chapter 22)

- Claisen and Dieckmann condensations
- Hydrolysis and decarboxylation of β-keto esters
- Alkylation of moderately basic enolate ions
- Synthesis using aldol and Claisen reactions
- Controlling the enolization of C=O compounds: Using lithium enolates
- Alkylation of lithium enolates

July 24: Enols, Enolates, and α,β-Unsaturated Compounds (Chapter 22)

- Crossed aldol and Claisen reactions
- Formation of enolates from α-bromo esters
- Introduction to α,β-unsaturated compounds: Nucleophilic addition
- Addition of dialkyl cuprates
- Kinetic (1,2) vs. thermodynamic (1,4) addition
- The Michael reaction

July 25: Enols, Enolates, and α,β-Unsaturated Compounds (Chapter 22)

- Robinson annulation
- A systematic approach to organic synthesis: Retrosynthetic analysis
- Organic synthesis using aldol, Claisen, Michael, and related reactions

Week 6

July 28: Exam 5

July 28: Chemistry of Amines (Chapter 23)

- Nomenclature, structure, and acid/base reactions of amines
- Preparation of primary amines: reduction of azides and nitriles
- Preparation of secondary and tertiary amines: reductive amination
- Amines from conjugate addition; amines from nitrile enolates

July 29: Chemistry of Amines (Chapter 23)

- Mannich reaction in the synthesis of natural amines
- 1,2-rearrangements to nitrogen: Beckmann, Hofmann, and Curtius rearrangements
- Synthesis and reactivity of aromatic amines
- Preparation and reactivity of aryl diazonium salts
- Using aryl diazonium salts in synthesis

July 30: Diels-Alder and Pericyclic Reactions (Chapters 15 & 27)

- Introduction to pericyclic reactions
- Molecular orbitals of conjugated π-electron systems
- Diels–Alder reaction
- Synthesis using the Diels-Alder reaction

July 31: Pericyclic Reactions (Chapter 27)

- Other cycloaddition reactions (incl. photochemical 2+2 cycloadditions)
- Electrocyclic reactions of conjugated dienes and trienes (thermal and photochemical)
- Sigmatropic reactions ([1.3], [1,5], [3,3] rearrangements)
- Summary of pericyclic selection rules

August 1: The Organic Chemistry of Life

- Key cofactors: Thiamine, NADH, and lipoamide
- Cholesterol biosynthesis and the role of statins
- Fatty-acid biosynthesis
- Polyketide biosynthesis

Week 7

August 4: Exam 6

August 5/6: Review Sessions

August 8: Final Examination

Chem S-20ab Laboratory General Information

Head Lab TF

Matt Patton *mpatton@g.harvard.edu*

Laboratory Section TFs

Shane Bouchard *sbouchard@college.harvard.edu*
Doug Evans *douglasevans@college.harvard.edu*
Nina Gu *ninagu@college.harvard.edu*
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Dave Rose *davidrose@g.harvard.edu*
Jolene Singh *singhjms@yahoo.com*

Location

The organic chemistry laboratory is located in Science Center 210 (across from the elevator). A Teaching Fellow (TF) must be present for you to enter the laboratory.

Overview

This laboratory course is designed to introduce you to the basic analytical and synthetic techniques employed in the practice of organic chemistry. **A passing grade for all experiments is required to pass the course.**

Any announcements related to lab will be posted on the Chemistry S-20ab website (http://isites.harvard.edu/k103796). However, some of the labs are accompanied by an instructional video. These pre-lab videos are required viewing and can be found under the heading "Pre-Lab Videos" on the Harvard Orgolabs website.

Scheduling

Laboratory sessions are scheduled for five consecutive hours (1 pm - 6 pm or 6 pm - 11 pm), every other day on a weekly basis. The first session will meet for an orientation led by the Head Lab TF, and then students will meet their TFs for a safety walkthrough, pre-lab quiz, pre-lab lecture, and the first experiment. Each subsequent lab will commence with a pre-lab quiz (more information follows) and a pre-lab lecture led by your TF. Quizzes will begin promptly at the beginning of the lab period. *Any student who is late to lab and misses the pre-lab quiz will not be permitted to make it up under any circumstances, and will receive a score of zero for that quiz.*

You will section for the laboratory during the first lecture. Lab assignments will be made shortly thereafter, and the first lab session will begin either on Wednesday, June 25th or Thursday, June

26th, depending upon your sectioning results. Lab exemptions will be granted exclusively to those students who have completed the labs associated with Chemistry 27, 20/30, E-2ab, or S-20ab here at Harvard. *There will be no exceptions*. Contact the Head Lab TF before labs begin if you have previously completed the lab component of any of these courses.

You will work with one other person to complete each experiment, but must submit all written work individually. Each student pair will be assigned their own chemical fume hood, and all chemical work must be performed in this hood.

Important Lab Safety Rules

The primary goal for the instructors of this laboratory is for each and every person (both students and TFs) to safely make it through the semester. Never endanger the safety of yourself or others for any reason. Detailed safety policies are outlined in the lab manual. However, the following items are so important that they will be stressed from the outset:

• Indirectly vented safety goggles (available for purchase at the Harvard COOP) **must** be worn in the lab **at all times**. They must be worn from the second you walk in until the second you leave, even if you are not doing chemistry. **The correct type of goggles will be shown at the first lecture, and photos are posted on the course website.** Although we may have extra goggles on hand from time to time, failure to show up to lab with your own goggles will automatically incur a safety/clean-up point penalty. Furthermore, any student who arrives at lab without goggles is at risk of being barred from that lab session altogether if there are no extra pairs to wear – always bring your goggles!

• You **must** wear proper attire to lab. This means no shorts or shoes that expose **ANY part of the foot or leg** are permitted in the laboratory. You will be immediately sent home to change if you attempt to enter the lab wearing shorts, capri pants, short dresses or skirts, sandals, flip-flops, "ballerina" flats, Toms, "boat" shoes, high-heeled boots or shoes, etc. – you will also receive a safety/clean-up point penalty to your grade for that lab (along with possibly forfeiting quiz points if you arrive late). You will *not* receive a warning before incurring this penalty. The best way to comply with policy and protect yourself from exposure is to **ALWAYS** wear long pants (a sturdy pair of jeans is best) and sneakers that cover the **entire** foot and ankle.

• You must wear one of the provided lab coats over your clothing at all times while working in the lab. Neither gloves nor lab coats should **ever** be worn outside the laboratory – they are contaminated!

• A Teaching Fellow (TF) must be present for you to enter the laboratory.

• Make-up labs will **NOT** be arranged for any students who miss a lab due to failure to adhere to our proper laboratory attire policies!

• There will be no exceptions to **any** of these policies as written.

Preparation

Nothing less than complete preparation prior to arriving in the organic chemistry laboratory is acceptable. Lack of preparation will retard your progress through the experiments, and will also result in danger to yourself, your TF, and your labmates. Contact your TF or the Head Lab TF if you have any questions about an experiment. See the lab manual for extensive details on preparation for each lab.

Required Materials

Text

The Organic Chem Lab Survival Manual: A Student's Guide to Techniques, 8th ed. by James W. Zubrick. This book is available at the Harvard COOP. You may come across other editions, which are acceptable, but you are responsible for figuring out the appropriate pages to read in any other editions, and some older editions may actually lack entire chapters assigned for reading, so be careful if you decide to purchase them.

Notebook

Your lab notebook must be the kind that makes carbon copies, so that a copy of your notes can be submitted to your TF at the end of each lab session. These research lab notebooks are available for purchase at the Harvard COOP, but you can buy them anywhere you wish. Students who arrive to lab without the proper laboratory notebook will be provided with a temporary replacement notebook on a *one-time basis*, but will incur a penalty to their grade for that lab, and will be refused participation in subsequent labs unless a satisfactory lab notebook has been procured. Students who arrive at lab without having completed the pre-lab write-up *in its entirety* present a danger to themselves and others and will be **barred from participating in that lab**. There will be no exceptions made for **any** student under **any** circumstances. Always come to lab prepared!!!

Lab manual

Available for purchase from FlashPrint, 99 Mount Auburn St. Copies of the lab manual should be available for purchase by the first lecture Monday June 23rd. ***Prior to the first experiment you must read and understand all of the introductory materials and the appendices to which they refer.*** Older editions of this lab manual are unacceptable.

Lab Safety Goggles

Available from the Harvard COOP. You must purchase your own and bring them to every scheduled laboratory session. Any student who shows up to lab without goggles will receive a clean-up point penalty for that lab session. No exceptions will be made under any circumstances. See above for more information on proper goggles.

Attendance

You must attend every one of your assigned laboratory sessions. The number of students enrolled in the course and our unwavering commitment to safety in the laboratory make it impossible for us to permit attendance of non-assigned laboratory sections without explicit permission from the Head Lab TF. Should a serious illness or family emergency arise, please notify the Head Lab TF and your own Lab TF as soon as possible, so we can work with you to help you complete all the experiments. If you have a religious conflict during the semester, please notify the Head Lab TF at least two weeks prior.

Grading

Your lab score will be calculated as follows:

10 Lab Reports	Pass/Rewrite
10 Labs with 2 Individual Clean-Up points each	20
10 Labs with 2 Group Clean-Up points each	20
10 Prelab Quizzes @ 9 points each	90
Total	130 points

Lab Reports

See the lab manual for a description of how to write good lab reports. Appendix 4 also shows an example of a passing report. Your TF will let you know of any more specific expectations he or she might have for your reports either prior to an experiment by e-mail or in the pre-lab talk. You will turn in your completed lab report **before** you leave each lab session. Your TF will then return your report in the next lab session with a grade of either **Pass** (an acceptably written report) or **Rewrite** (if any part of the report is unsatisfactory or incomplete). Should you receive a grade of Rewrite, you will have until the next lab session to satisfactorily revise your report and turn it back in to your TF for regrading in order to pass that lab (and ultimately the course).

Failure to complete all of the lab experiments and all of the write-ups will result in a failing grade for the course.

Pre-lab Quizzes

The pre-lab quizzes are designed to test practical understanding of the procedures, safety considerations, and fundamental chemical concepts as explained in this manual, your textbook/lecture notes, and in Zubrick. You will be asked three questions directly (that is, verbatim) from the "Possible Quiz Questions" section of each experiment. The quizzes require that you do all required reading and *think about the lab* in advance. It is entirely possible to earn a perfect score on every lab quiz. Since the quizzes will begin promptly at the start of each lab, you will ***not*** have time (or be permitted) to ask your TF for help on the quiz questions then. Be certain to have any questions answered BEFORE coming to lab! Your TF is always available by e-mail to help you with the quiz material, although if you expect to be able to have all of your answers "checked over" by your TF, you will be sorely disappointed. Help Room is a great place

to ask any questions you may have about the lab material, as there will always be lab TFs around to provide assistance. If you have questions about the quiz material for Lab 1, please e-mail the Head Lab TF. Students who arrive late to lab will be given **no** additional time to complete the lab quizzes. As mentioned above, students who arrive **after** the pre-lab quizzes have already been given and collected will NOT be permitted to take the quiz, and will receive a score of zero on that quiz. Be on time!

Personal Clean-Up/Safety Points

You will earn up to two points in each lab session for obeying all safety regulations and leaving your fume hood, bench-top, sink, and drying rack in immaculate condition at the end of each lab. In order to earn these points, it is your responsibility to have your TF initial your notebook at the end of the lab period to verify that you did in fact leave your work area clean. For a description of exactly what is expected of you, refer to Appendix 3 of the lab manual. Failure to adhere to ***ANY*** rules and regulations of the laboratory could result in losing your personal safety/clean-up points for that session, at your TF's discretion and as mentioned above. Please note that your TF may assign groups to handle additional clean-up tasks, and failure to complete these tasks could also result in personal safety/clean-up point deductions.

Group Clean-Up/Safety Points

Each lab section will earn up to two points as a group each week for properly following waste disposal rules, handling reagents responsibly, and keeping all common areas in the lab clean. These include the waste disposal hoods, center bench reagent dispensing areas, balances and melting point apparatus areas, glassware room and bins, white shelves, and the instrument room. Leaving reagents uncapped will result in an automatic group safety point deduction. Leaving pipets in the center bench hood or spatulas by the balances will also result in a group safety point deductions. Failure to keep these areas spotless will result in the entire laboratory section losing up to two points for that lab session, at the Head Lab TF's discretion. The easiest way to avoid this is to always be sure to clean up after yourself!

Chemistry S-20ab Laboratory
Summer 2014 Syllabus

Date	*Lab #*	*Lab Description*
June 25-26	0 1	**Orientation and Safety Walkthrough** **Separation of an Unknown Mixture** Acid-Base Properties and Solvent Extraction
June 30-July 1	2	**Purification of Organic Compounds** Recrystallization and Distillation; Begin Lab 3
July 7-8	3	**Chirality and Optical Activity** Resolution of Racemic Phenethylamine Separation of Diastereomers; Polarimetry
July 9-10	4	**Electrophilic Addition and E2 Elimination** Synthesis of Diphenylacetylene Infrared Spectroscopy Reactivity of α-Pinene
July 14-15	5	**The Grignard Reaction** Preparation of the Grignard Reagent Synthesis of Triphenylmethanol
July 16-17	6	**Chromatography I** "Green" & Friedel-Crafts Acylation of Ferrocene Thin-Layer Chromatography
July 21-22	7	**Chromatography II** "Flash" Column Chromatography
July 23-24	8	**Esterification** Synthesis of Isoamyl Acetate Synthesis of Aspirin Synthesis of Oil of Wintergreen
July 28-29	9	**The Wittig Reaction/Chemiluminescence/Multistep Synthesis of 1,2,3,4-Tetraphenylnaphthalene I** Synthesis of an Anthracene Derivative Double Aldol Condensation
July 30-31	10	**Multistep Synthesis of 1,2,3,4-Tetraphenylnaphthalene II** Diels-Alder Reaction with Benzyne

Note 1: The actual day of the week you conduct each lab will depend on which section you are assigned to.

Note 2: You will be conducting Lab 1 on your first assigned day of lab. Before you show up, you **must** read the Introduction section of the lab manual and complete your Pre-Lab for Lab 1.

Note 3: Unexcused absences from lab are not permitted. Contact Matt Patton, Head Lab TF (e-mail: mpatton@g.harvard.edu) in case of a medical emergency. The attendance policy is detailed in the lab manual.