CHM 343H: Organic Synthesis Techniques

Course Syllabus: Spring 2018

This laboratory course showcases modern organic synthesis techniques and introduces chemical research principles. It provides excellent preparation for a CHM 499Y project in organic chemistry. Associated classes teach theory and problem-solving approaches from a practical perspective and through industrial case studies. Green chemistry decision-making is a central theme of both the class and laboratory components.

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Overview of Course:

CHM 343H is a synthetic course designed to provide the opportunity of developing practical skills in the following areas:

- synthesizing organic compounds, primarily on a microscale/semi-microscale, **WITH A PARTICULAR EMPHASIS ON MODERN CATALYTIC METHODOLOGIES AND OTHER ASPECTS OF GREEN CHEMISTRY**
- proving the structure of the compounds by application of modern physical methods
- analyzing the purity of the prepared compounds by different techniques

The CHM 343H class material has been designed to closely align with the practical work. Classes have heavy emphasis on NMR spectroscopy at the beginning of the course in order to assist with laboratory spectral interpretation. The laboratory importantly showcases the relevance and importance of organic synthesis in "everyday life". Highlights include:

- Preparation of (i) a pharmaceutical currently prescribed as an anti-depressant; (ii) a non-steroidal anti-inflammatory drug analog; and (iii) a sunscreen analog (featuring phase-transfer catalysis and organocatalysis in a multi-step synthesis)

- Green chemistry: (i) using water to replace common organic solvents under conditions of palladium catalysis; (ii) microwave heating as an alternative to traditional reflux; and (iii) calculation and interpretation of important green metrics such as reaction mass efficiency (RMI) and process mass intensity (PMI)

- A "plan-your-own" alcohol oxidation based on a recent catalytic literature method

- A multi-step "unknown" synthesis that involves complete student design and execution

- A laboratory practical examination focused around a fundamental reaction life-cycle analysis

It is anticipated that you will develop a greater appreciation and understanding of the synthetic methodology and structure elucidation approaches that organic chemists use on a daily basis throughout the world. You will also be exposed to modern purification methods including small-scale flash column chromatography, and learn how to process your own NMR spectra for each compound you synthesize. This will allow you to use NMR in a quantitative sense (for example, by calculating product purity and diastereomer ratios).

Below you will find the *provisional* list of class topics for CHM 343H:

• Anatomy of a Reaction (synthetic planning, reaction set-up and analysis, product purification)
• NMR Spectroscopy
• Synthetic Principles
• Green Chemistry
• Transition Metal Catalysis (cross-coupling reactions, metathesis)
• Asymmetric Synthesis
• Organocatalysis

Marking Scheme:

The course material is acquired through laboratory experiments, problem solving, classes and course readings. The overall course grade is determined by a combination of factors based on your performance in two assignments, examinations and in the laboratory:

Assignments	10%
Term Test	10%
Laboratory	45%
Final Exam	35%

*****NOTE:** The practical skills acquired in CHM343H are an extremely important aspect of this course. As such, you are required to attend *at least* six complete experimental sessions in order to pass this class. Students who fail to attend enough practical sessions, even if justified with a medical note, will not receive credit for CHM343H since they will not have acquired the practical skills expected of a student who has completed this course.

Term Test – Wednesday February 14th 2018 (4:00–5:00 pm) – *10% of final grade*

Assignments

- *Structure-Based Databases (SciFinder) – 5% of final grade*
  Due date: **Friday January 19th 2018** by 4:30 pm (10% deducted per day late)
- *Green Chemistry Assignment – The Buchwald-Hartwig Amination – 5% of final grade*
  Due date: **Wednesday March 14th 2018** at the start of class (10% deducted per day late)
  Important aspects of the assignment will be explained in class on **Wednesday February 28th 2018**

Laboratory Practical Exam – April 2nd/3rd 2018

Important Dates: Last day to drop the course without penalty – **Wednesday March 14th 2018**
Reading week (no classes) – **Monday February 19th – Friday February 23rd 2018**

Classes:
LM 155: Mondays and Wednesdays from 4:00 – 5:00 p.m.
Please come prepared by having done any assigned reading, and printed out in advance any class notes posted online. Questions are particularly welcomed during class.

Office Hours (Prof. Rousseaux):
DB 475 (access is through the A.D. Allen Chemistry Library in the Davenport Wing of Lash Miller)
Monday 5:00–6:00 pm and Wednesday 3:00–4:00 pm

I will also meet with students by appointment. *It is best to meet with me in my office during office hours or by appointment, rather than use email.* If you do use e-mail, please include the course code CHM 343H in the title and use your UofT e-mail address. Also, in preparation for examinations, please do not leave all of your questions until the last minute!

Office Hours (Prof. Dicks):
LM 118: Available during laboratory time, MT 10:00 a.m–1:00 p.m., R 9:00 a.m.–12:00 p.m. (starting the week of Monday January 15th). You are highly recommended to ask questions and are also very welcome to make an appointment to do so by e-mail.

Course Web-page: https://portal.utoronto.ca/

Available by logging on to "Blackboard" using your UTORID/password and then navigating through the "My Courses" section opening the CHM 343H page (called "Organic Laboratory"). Various options are then available on the left-hand side navigation bar.

Material that will be posted on the web-site include laboratory information, class notes, supplementary material and other course updates. ***Please check regularly for updates***. Normally new class notes will be posted by 5 pm the day before classes. You should print these out and bring them to class. Note: although in some cases you may be able to print notes as 2 per page, *for legibility reasons many of the NMR's handouts should be printed out as one spectrum per page.*

Accessibility: The University of Toronto is committed to accessibility. If you require accommodations for a disability, or have any accessibility concerns about the course, the classroom or course materials, please contact Accessibility Services as soon as possible: disability.services@utoronto.ca or http://studentlife.utoronto.ca/accessibility.

Academic Integrity:

Academic integrity is fundamental to learning and scholarship at the University of Toronto. Participating honestly, respectfully, responsibly, and fairly in this academic community ensures that the U of T degree that you earn will be valued as a true indication of your individual academic achievement, and will continue to receive the respect and recognition it deserves. Familiarize yourself with the University of Toronto's *Code of Behaviour on Academic Matters* (www.governingcouncil.utoronto.ca/policies/behaveac.htm). It is the rule book for academic behaviour at the U of T, and you are required to know the rules. If you have any concerns or need for clarification about aspects of the *Code*, please contact Professor Dicks.

Turnitin:

Normally, students will be required to submit their laboratory reports to turnitin.com for a review of textual similarity and detection of possible plagiarism. In doing so, students will allow their reports to be included as source documents in the turnitin.com reference database, where they will be used solely for the purpose of detecting plagiarism. The terms that apply to the University's use of the turnitin.com service are described on the turnitin.com web site. More information will be provided about the use of Turnitin as the semester progresses.

Textbook and Course Aids:

A general and very useful textbook for organic chemistry is *Organic Chemistry* (Second Edn.) by Clayden, Greeves and Warren (Oxford University Press).

A highly recommended e-book regarding organic practical techniques is *The Synthetic Organic Chemists Companion* (M. Pirrung, John Wiley & Sons, Inc.). This e-book is available through the UofT library service.

Not only are these books useful for CHM 343H, but they will come in very handy if you intend to pursue any aspect of organic synthesis in the future as an undergraduate or graduate student.

"Not Voodoo": Demystifying Synthetic Organic Chemistry Laboratory Technique
http://chem.chem.rochester.edu/~nvd/
Is a very useful website for experimental and laboratory information on organic synthesis.

Knowledge and Concepts that are assumed for this Course:

1st and 2nd Year Organic Chemistry (i.e. CHM 136H/138H/151Y and CHM 247H/249H)

- Basic Structure and Bonding
- Basic Thermodynamics and Kinetics: describing reactions using energy diagrams
- Acidity and Basicity
- Basic NMR, IR & MS Spectroscopy of Organic Molecules
- Stereochemistry of organic compounds, stereocentres, *R* and *S* configurations, optical activity, *meso* compounds etc.
- Structure and reactivity of alkenes and alkyl halides
- Aromaticity
- Chemistry of Alkenes and Alkynes
- Aromatic Compounds (Substitution Chemistry)
- Amines
- Aldehydes and Ketones
- Carboxylic Acids and their Derivatives
- Enolate Chemistry

Material from CHM 342H and CHM 348H is also useful preparation, but it is ***not*** assumed for this course.

Handouts from CHM 249H:

Handouts/problem sets on introductory NMR spectroscopy are available on the CHM 249H website. We will review and build upon this material in the course preparation for CHM 343H.

The CHM249 notes are protected, and are accessible using the userid = "chm249" and the password = "quinine" from the CHM 249H website:
www.chem.utoronto.ca/coursenotes/CHM249/CHM249HNotes.html

The relevant material appears under the heading "Application of IR and NMR Spectroscopy"

Laboratory:

LM 113: Mondays or Tuesdays from 8:30 a.m. – 1:00 p.m.

Laboratory Requirements:

1. **Safety glasses & laboratory coat** – to be brought to each practical session.

2. A **NEW**, hard cover laboratory notebook (please do not use a notebook from a previous course).

3. A pair of **PURPLE or BLUE nitrile gloves** (not grey ones) per experiment. **No gloves are available from the preproom for use in the laboratory.**

During The First Week

1. You will purchase the laboratory manual (see below). Make sure you read and understand the sections of the manual entitled "Policy Regarding Academic Discipline" (page 2) and "Laboratory Safety" (pages 122-124).

2. **Please come to laboratory LM 113 at the correct assigned time according to your demo group! See the 'Laboratory Information' page on the CHM 343H Blackboard site for your demo group assignment during the first week of January):**

Group 11: Monday 8th January, 10:00 a.m.
Group 12: Monday 8th January, 11:00 a.m.
Group 21: Tuesday 9th January, 10:00 a.m.
Group 22: Tuesday 9th January, 11:00 a.m.

3. You will hear background information about the laboratory. Locker check-in and the first experiment (Preparation of an Anti-Depressant via Amine Acylation: Synthesis of Moclobemide) will be performed on Monday 15th/Tuesday 16th January in LM 113.

PLEASE BRING $10.00 TO BUY THE LABORATORY MANUAL ON MONDAY 8th/TUESDAY 9th JANUARY – IT WILL NOT BE SOLD AT ANY OTHER TIME. IN ADDITION, $20.00 IS REQUIRED AS A LOCKER DEPOSIT ON MONDAY 15th/TUESDAY 16th JANUARY.

Important Notes Regarding the Laboratory:

1. The lab starts exactly on the half-hour (8:30 am sharp).

2. There will a quiz during first 10 minutes of the lab (including one on 15th/16th January). If you are late, you will not be allowed to write a quiz - "late" means any time after 8:30 a.m.

3. If you are late by more than 15 minutes, you will not be allowed to perform the experiment.

4. There are no make-ups. The labs are only on Monday/Tuesday mornings every week.

5. Remember to bring your safety glasses (goggles), a lab coat, nitrile gloves and a notebook on 15th/16th January - you will be undertaking experimental work.

6. It is required that you download a free copy of **ChemDraw Professional 16 or 17** to use in writing laboratory reports. This powerful software allows you to draw chemical structures (and check them) easily and quickly and is used daily by researchers worldwide. Its use is an important part of your chemical training. More information is available at: www.chem.utoronto.ca/facilities/chemlib/

7. For more details of laboratory information, including document and ChemDraw templates and preparing and submitting lab. reports, please consult the course site on Blackboard.

Schedule of Laboratory Experiments:

Laboratory days are Mondays and Tuesdays, **8:30 a.m. – 1:00 p.m.** The first experiment will be performed on January 15th (Monday groups) and January 16th (Tuesday groups).

1. Locker Check-In & Preparation of an Anti-Depressant via Amine Acylation: Synthesis of Moclobemide (Manerix®) (15th/16th January)

2. Sunscreen Preparation (Part 1) – Aqueous Methylation of 4-Hydroxybenzaldehyde & Reduction of 4-*t*-Butylcyclohexanone with Sodium Borohydride (22nd/23rd January)

3. Sunscreen Preparation (Part 2) – Verley-Doebner Modification of the Knoevenagel Condensation & Reduction of 4-*t*-Butylcyclohexanone with Sodium Borohydride (continued) (29th/30th January)

4. Sunscreen Preparation (Part 3) – Synthesis of an Ultra-Violet Light Absorber (5th/6th February)

5. "Plan-Your-Own" Alcohol Oxidation (12th/13th February)

READING WEEK 19th – 23rd FEBRUARY

6. Environmentally Friendly Palladium Catalysis in Organic Synthesis: A Sonogashira Reaction (26th/27th February)

7. The Buchwald-Hartwig Cross-Coupling Reaction (Green Chemistry Assignment Practical Work) (5th/6th March)

8. Energy Efficiency of an Organic Reaction: Suzuki NSAID Analog Synthesis under Conventional & Microwave Heating (12th/13th March)

9. "Design-Your-Own" Multi-Step Synthesis (1) (19th/20th March)

10. "Design-Your-Own" Multi-Step Synthesis (2) (26th/27th March)

11. Laboratory Examination, Locker Clean-up & Check-Out (2nd/3rd April)

Summer Research Opportunities:

The **Undergraduate Summer Research Fellowship Program** in the Department encourages qualified students to broaden their experience in chemistry by doing research during the summer months under the supervision of a chemistry faculty. These are meant to encourage students to undertake graduate studies and pursue a research career in chemistry. These research activities are held in the research labs located in the Lash Miller Buildings in the St. George campus. Two main programs are the NSERC USRA and the OSOTF scholarships described on the website listed below.

Applications are due at the undergraduate office (LM 151) by **January 15th 2018**.

Details of the application procedure and requirements can be found at:
www.chem.utoronto.ca/~undergrd/Summer/Research/home.html