Chemistry
UNIVERSITY OF TORONTO

CHM 343H: ORGANIC SYNTHESIS TECHNIQUES

Winter 2025 Course Syllabus

I TEACHING TEAM

INSTRUCTOR
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LABORATORY & COURSE COORDINATOR
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TEACHING ASSISTANTS

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NMR Demonstrator:

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II COURSE OVERVIEW

A very warm welcome to CHM 343H! This course teaches fundamental organic synthesis techniques and introduces chemical research principles, primarily through the lens of catalytic reactivity. The classes teach important theory and problem-solving approaches from a practical perspective and through industrial case studies. As CHM 343H is required as part of our departmental Focus in Green Chemistry, green chemistry decision-making is a central theme of both the class and laboratory components. CHM 343H builds extensively on material discussed in second-year prerequisite courses

(CHM 247H or CHM 249H), and **a thorough understanding of organic chemistry concepts covered in these courses is essential for success.** *CHM 343H is recommended for students enrolled in any Chemistry specialist, major or minor program, and is required as part of the Synthetic & Catalytic Chemistry specialist program. The course provides excellent preparation for a CHM 395Y or CHM 499Y research project in the broad field of organic chemistry.*

We sincerely hope that CHM 343H will exceed your expectations: we are all here to support your learning and are very invested in your success! We would appreciate your comments and suggestions so that we can make the course as helpful and interesting as possible: do feel free to discuss any matters with Professor Luska, Professor Dicks and the laboratory teaching assistants (TAs).

STUDENT LEARNING OUTCOMES:
Upon successful completion of this course, students will be able to:

- articulate and apply the principles of the "anatomy" of an organic reaction (synthetic planning, reaction set-up and analysis, product isolation, purification and characterization)
- apply the structural elucidation technique of nuclear magnetic resonance (NMR) spectroscopy *in order to* determine the atom connectivity and stereochemistry of both known and unknown molecules
- apply principles of transition metal catalysis, organocatalysis, and other catalytic strategies to propose synthetic routes to target compounds
- describe various approaches towards asymmetric synthesis and apply them to propose the synthesis of molecules with defined stereochemistry
- collect, record, and interpret laboratory results
- safely synthesize and characterize a range of organic compounds by using a variety of classic techniques and modern instrumentation, with a particular emphasis on modern catalytic methodologies and other aspects of sustainability
- design synthetic pathways for laboratory testing that exemplify principles of green chemistry by modification of literature procedures
- develop effective scientific communication skills through the writing of reports for different audiences in "journal-style" format.

PREREQUISITE COURSES:
This course assumes you have a fundamental and thorough understanding of content presented in either CHM 247H (Introductory Organic Chemistry II) or CHM 249H (Organic Chemistry). *Concepts covered in CHM 342H (Modern Organic Synthesis) and CHM 348H (Organic Reaction Mechanisms) are useful, but neither course is a prerequisite for CHM 343H*. CHM 343H is itself a prerequisite course for CHM 441H (Spectroscopic Analysis in Organic Chemistry).

Specific knowledge & concepts from CHM 247H/CHM 249H that are *assumed* for CHM 343H:

- basic organic structure and bonding
- basic thermodynamics and kinetics: describing reactions using energy diagrams
- acidity and basicity of organic compounds
- basic principles of NMR spectroscopy and IR spectroscopy
- stereochemistry of organic compounds (stereocentres, *R*, *S*, *E*, *Z* configurations, optical activity, *meso* compounds etc.)
- structure and reactivity of alkenes, alkynes and alkyl halides

- aromaticity and aromatic reactivity
- amine preparation and reactivity
- chemistry of aldehydes and ketones
- chemistry of carboxylic acids and their derivatives
- enolate formation and reactivity

REFERENCE MATERIAL:
A general and very useful textbook for synthetic organic chemistry is *Organic Chemistry* (Second Edn.) by Clayden, Greeves and Warren (Oxford University Press). In addition, 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. Finally, *"Not Voodoo": Demystifying Synthetic Organic Chemistry Laboratory Techniques* is a very useful website for experimental and laboratory information on organic synthesis.

III HOW THE COURSE IS ORGANIZED

OVERVIEW:
CHM 343H has two instructional components – classes and laboratories. **As per the Faculty of Arts & Science timetable, all instruction will be delivered in-person as of Monday 6th January.** An announcement will be made if the delivery mode of any or all instructional components needs to change for any reason. Laboratories are scheduled to run in-person on Monday and Tuesday mornings, starting during the week of Monday 13th January.

CLASSES:
Classes will be offered in-person ONLY throughout the semester on Monday and Wednesday from 3–4 p.m. in SS 1087 (Sidney Smith Commons, 100 St. George St.). Please come prepared to class with a print or electronic copy of the class notes posted on the Quercus course website. Questions are particularly welcomed both during class time and after class. Do be aware that reading the posted class notes and/or textbook is not a substitute for attending classes and taking an active approach to your learning! It is essential that you attend class in-person in order to solidify your understanding of the fundamental course material.

A list of planned topics that will be covered in class is as follows:

- 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
- asymmetric synthesis
- organocatalysis

LABORATORIES:
The laboratories are a mandatory component of CHM 343H and are held in-person on MT from 8:30 a.m. – 1 p.m. in room LM 113. You will find that they showcase the relevance and importance of organic synthesis in "everyday life" and are very closely and deliberately aligned with the material discussed during class time. Several highlights of the planned practical work are as follows:

- preparation of (i) a pharmaceutical currently prescribed as a local anesthetic; and (ii) a sunscreen analog (featuring catalysis in a multi-step synthesis, which will lead to one student winning the CHM 343H "Sunscreen Cup"!)
- green chemistry principles and practice, for example: (i) using water as a solvent under transition metal-catalyzed conditions; and (ii) calculation and interpretation of important mass metrics such as reaction mass efficiency (RME) and process mass intensity (PMI) as part of a "Future Leaders in Green Chemistry" assignment activity
- a "plan-your-own" alcohol oxidation based on a catalytic literature method
- a multi-step, two-week "design-your-own" synthesis that involves entire student planning and execution

The planned schedule of experimental work (seven experiments spread over eleven weeks) is as follows:

1. Locker Check-In & ***Experiment 1*****:** Preparation of an Anesthetic via Acylation and Substitution Reactions: Synthesis of Lidocaine (Xylocaine) (13^{th}/14^{th} January)

2. ***Experiment 2*****:** The Sunscreen Cup (Part 1): Etherification of 4-Hydroxybenzaldehyde Featuring a Greener Methylation Agent (20^{th}/21^{st} January)

3. The Sunscreen Cup (Part 2): Organocatalysis in Action: Verley-Doebner Modification of the Knoevenagel Condensation (27^{th}/28^{th} January)

4. The Sunscreen Cup (Part 3): Final Synthesis of an Ultra-Violet Light Absorber (3^{rd}/4^{th} February)

5. ***Experiment 3*****:** A "Plan-Your-Own" Catalytic Alcohol Oxidation (10^{th}/11^{th} February).

WINTER READING WEEK: 17^{th} – 21^{st} FEBRUARY

6. ***Experiment 4*****:** Environmentally Friendly Palladium Catalysis in Organic Synthesis: A Sonogashira Reaction (24^{th}/25^{th} February).

7. ***Experiment 5*****:** Asymmetric Organocatalysis (Part 1): Synthesis of Chiral Alcohols via a Proline-Catalyzed Aldol Reaction & ***Experiment 6*****:** Optimizing an Aqueous Catalytic Cross-Coupling Reaction to Synthesize a Biaryl NSAID Analog (Part 1) (3^{rd}/4^{th} March).

8. Asymmetric Organocatalysis (Part 2) & Optimizing an Aqueous Catalytic Cross-Coupling Reaction to Synthesize a Biaryl NSAID Analog (Part 2) (10^{th}/11^{th} March).

9. Assessing the Sustainability of a Buchwald-Hartwig Cross-Coupling in Synthesizing Industrially Relevant Compounds (Future Leaders in Green Chemistry Assignment Practical Work) (17^{th}/18^{th} March)

10. ***Experiment 7*****:** A "Design-Your-Own" Multi-Step Synthesis (1) (24^{th}/25^{th} March)

11. A "Design-Your-Own" Multi-Step Synthesis (2) Locker Clean-Up & Check-Out (31^{st} March/ 1^{st} April).

More information about the practical component of the course will be discussed during the mandatory introductory workshops held during the mornings of Monday 6th/Tuesday 7th January.

Information Regarding Use of Artificial Intelligence Tools in the Writing of Laboratory Reports:

Generative Artificial Intelligence (AI) technology is evolving quickly, and it is necessary to specifically address this within the context of CHM 343H laboratory reports. AI tools such as ChatGPT (GPT stands for Generative Pre-trained Transformer) are large language models that have been trained on a limited dataset to generated content based on prompts and the data it has been trained on. **It is important to recognize there are major limitations to these tools, particularly in more specialized subjects such as chemistry.** Currently, ChatGPT and many similar models are only trained on freely available data and will not include information that is only accessible through payment, which includes much of the scholarly literature, textbooks, etc. (There is a lot of reliable information on the internet, but there is also a lot of junk, and ChatGPT does not know how to tell the difference: it has no concept whatsoever of scientific accuracy). In addition, ChatGPT does not cite its sources: when asked to include citations, it will routinely reference papers that do not exist. By using ChatGPT to generate text, you run the risk of accidentally plagiarizing one of the many sources that are included as part of its training data.

Two important learning outcomes from the laboratory component of CHM 343H are (i) development of effective scientific communication skills through written laboratory reports; and (ii) use of scientific literature to understand and evaluate experimental procedures and results. The practice and repetition of writing on your own has been shown in numerous scientific reports to lead to deeper and longer lasting learning. *In this course, the use of ChatGPT and/or other generative AI tools is permitted within the limitations of reviewing your own written work for additional suggestions of grammar, punctuation, etc*. In this manner, the tool is educational and can help you develop better writing skills when used critically and for self-analysis. **However, it is both ill-advised and prohibited to solely use these tools to attempt to write or analyze components of formal laboratory reports.** As mentioned previously, the capabilities of the systems are limited, and you will not develop the scientific communications skills needed for future studies or careers. **In summary, it is well established that these tools will misuse and fabricate information and referencing, which will be noticeable by your TAs and laboratory instructors and will leave you susceptible to academic discipline violations (see the "Academic Integrity" section on p. 9 of the syllabus).**

IMPORTANT WINTER 2024 SESSIONAL DATES:
First Day of S classes: Monday 6th January 2025
Family Day: Monday 17th February 2025
Winter Reading Week (no classes): Monday 17th – Friday 21st February 2025
Last Day to Drop S Courses: Monday 10th March 2025
Last Day of S classes: Friday 4th April 2025
Study Days: Monday and Tuesday 7-8th April 2025
April Final Assessment Period: Wednesday 9th – Wednesday 30th April 2025
Good Friday: Friday 18th April 2025

IV EVALUATION/GRADING SCHEME

OVERVIEW:
The course material is acquired through laboratory experiments, problem solving, classes, and course readings. Your overall course grade is determined by a combination of factors based on your performance in the laboratory (including three formal reports), in one term test, in two assignments, and in a final examination:

Laboratory: 45%*
Term Test: 10% or 15%**
"Design-Your-Own" Synthesis Proposal Assignment: 10%
"Future Leaders in Green Chemistry" Assignment: 10%
Final Examination: 25% or 20%**

ASSESSMENT DATES & MARK BREAKDOWN:
1. Laboratory (45%*, throughout semester). Quality of practical work/results/submitted products and three formal written laboratory reports. A detailed breakdown of the laboratory grading scheme is available on the CHM 343H Quercus site.

2. Term Test (10% or 15%**, in-person, Monday 3rd March, 3:10–4:00 p.m. in room EX 320, written during regularly-scheduled class time).

3. "Design-Your-Own" Synthesis Proposal (10%). Each student will be given an individualized target compound to plan the synthesis of, given a defined starting material. Information regarding this will be provided during laboratory time on Monday 10th/Tuesday 11th February: the proposal is due by 9 a.m. on Monday 24th February (10% deducted per day late to a maximum of two days).

4. "Future Leaders in Green Chemistry" Assignment (10%). One specific class hour will be dedicated in mid-March to explaining the nature of this assignment. The assignment is due by 9 a.m. on Friday 4th April (10% deducted per day late to a maximum of two days).

5. Final Examination (25% or 20%**, in-person, April final examination period, Wednesday 9th – Wednesday 30th April). *The actual date of the final examination will be set by the Faculty of Arts & Science and could occur on the last date mentioned*.

***the practical skills acquired in CHM 343H are an extremely important aspect of this course. As such, you are required to attend at least eight complete experimental sessions in order to pass this class. Students who fail to attend enough practical sessions, even if justified with documentation, will not receive credit for CHM 343H since they will not have acquired the practical skills expected of a student who has completed this course.**

**each student will have their final course grade calculated in two ways, with the combined term test + final examination total being worth 35%. Students will receive the higher of the two resulting final grades.

V IMPORTANT COURSE POLICIES

- Each member of this course is expected to maintain a:

    - professional and respectful attitude during all course components, including classes, laboratories, assessments and any online activity
    - personal calendar/schedule/organizer to ensure that all course activities are completed, and due dates are met
    - collection of notes recorded independently based on concepts covered in course activities (students registered with Accessibility Services requiring a class note-taker will have access to this accommodation)
    - familiarity with the university policy on Academic Integrity (overleaf)

- Course website: q.utoronto.ca (in your Quercus Dashboard, click on "CHM 343H Winter 2024"). **Please check the Quercus course website regularly for**:

    - general course information
    - all specific laboratory information
    - class notes
    - all important announcements related to assessments and laboratories

- Email will generally be responded to within 24 hrs. on weekdays. Email will only be accepted if: (1) You send it from your utoronto.ca account; (2) You identify yourself in the email subject as a student in CHM 343H and include your name and University of Toronto student ID number; (3) No attachments are sent, unless official university correspondence is being forwarded (e.g., a letter detailing academic accommodations or an ACORN absence declaration); (4) You are aware that organic chemistry can be talked about much more effectively through student hours rather than by email, and that sending emails is not a substitute for attending classes. The finalized student hours for each instructor will be posted at the Quercus course website and they are additionally available by appointment.

  Important: be sure to email only ONE person within the CHM 343H instructional team, depending on the nature of your concern. Please do not send emails through the Quercus internal email system (they will not be responded to): the contact information for the course instructor/laboratory coordinator/teaching assistants is listed on p. 1 of the syllabus.

- The University of Toronto is committed to equity, human rights and respect for diversity. All members of the learning environment in this course should strive to create an atmosphere of mutual respect, where all members of our community can express themselves, engage with each other, and respect one another's differences. As members of the course teaching team, we will not tolerate behaviour that undermines the dignity or self-esteem of any individual in this course and wish to be alerted to any attempt to create an intimidating or hostile environment. It is our collective responsibility to create a space that is inclusive and welcomes discussion. Discrimination, harassment and hate speech will not be tolerated. If you have any questions, comments, or concerns, we encourage you to reach out to the staff in our Equity Offices.

- Students may not create audio or video recordings of classes except for those students requiring an accommodation for a disability, who should contact the instructor prior to beginning to record classes for written permission. Students creating unauthorized audio recording of classes violate an instructor's intellectual property rights and the Canadian Copyright Act. Students violating this agreement will be subject to disciplinary actions under the Code of Student Conduct.

- Assignments and laboratory reports are to be submitted through the CHM 343H Quercus course website only. Late assignments and reports will be deducted at 10% per day to a maximum of two days, **after which they will not be graded**.

  There is no make-up test in CHM 343H, and there are no make-up laboratory sessions. If you are absent from your studies due to illness or other reasons and are unable to complete course work (e.g., a term test or a laboratory report) then a piece of written documentation is required. The following four items are the recognized forms of documentation:

  1. Absence Declaration via ACORN (please note that this Declaration can be used for health reasons, personal or family emergencies, or bereavement and can only be used once per semester for a maximum of seven consecutive days: see website for full details)
  2. U of T Verification of Illness or Injury Form
  3. College Registrar's letter
  4. Letter of Academic Accommodation from Accessibility Services

  Students who complete the ACORN Absence Declaration form must additionally contact Professor Dicks regarding a missed laboratory session or Professor Luska regarding a missed term test to discuss their situation. This needs to be done within five business days of the missed work and is essential action for any consideration to be granted.

  For extended absences and for absences due to non-medical reasons, make sure to contact your College Registrar's Office. They can help you decide between a request for an extension or other types of academic consideration.

- If you suspect or know that you have a disability that is affecting your studies, learn about the services and supports available through Accessibility Services. A disability can be physical disability, sensory disability, a learning disability, mental health disorder or a short-term disability like an injury. If you are not sure whether you have a disability, you can confidentially contact Accessibility Services with your questions.

VI TECHNOLOGY REQUIREMENTS

- This course requires the use of computers, and technical issues are possible. When working on a piece of work such as a laboratory report, students are responsible for scheduling enough time to allow for reasonable delays due to technical difficulties to be overcome, so such issues will not be acceptable grounds for deadline extension. Particularly, maintaining an up-to-date, independent backup copy of your work is strongly recommended to guard against occurrences such as hard-drive failures, corrupted files, lost computers, etc. *We encourage you to spend a moment at the start of the semester to plan for what you would do if you lost access to the computer that you primarily intend to use, which will help ensure that you are prepared for this unlikely possibility.*

VII INSTITUTIONAL POLICIES AND SUPPORT

ACADEMIC INTEGRITY:
Academic integrity is essential to the pursuit of learning and scholarship in a university, and to ensuring that a degree from the University of Toronto is a strong signal of each student's individual academic achievement. As a result, the University treats cases of cheating and plagiarism very seriously. The University of Toronto's Code of Behaviour on Academic Matters (governingcouncil.utoronto.ca/secretariat/policies/code-behaviour-academic-matters-july-1-2019) outlines the behaviours that constitute academic dishonesty and the processes for addressing academic offences. Potential offences include, but are not limited to:

In assignments/laboratory reports:

- using someone else's ideas or words without appropriate acknowledgement.
- submitting your own work in more than one course without the permission of the instructor.
- making up sources or facts.
- obtaining or providing unauthorized assistance on any report. **Please note that the use of websites (such as Chegg.com) to post assignment/laboratory report questions or to post/access answers to questions is an academic offence under the University of Toronto's Code of Behaviour on Academic Matters. Alleged instances of this nature are forwarded to the Faculty of Arts & Science Student Academic Integrity office.**

On term tests:

- using or possessing unauthorized aids.
- looking at someone else's answers or collaborating/discussing answers during a term test.
- misrepresenting your identity.

In general academic work:

- falsifying institutional documents or grades.
- falsifying or altering any documentation required by the University.

All suspected cases of academic dishonesty will be investigated following procedures outlined in the Code of Behaviour on Academic Matters. If you have questions or concerns about what constitutes appropriate academic behaviour or appropriate research and citation methods, you are expected to seek out additional information on academic integrity from your instructor or from other institutional resources (see www.academicintegrity.utoronto.ca).

PLAGIARISM DETECTION:
Normally, students will be required to submit their course essays and tests to the University's plagiarism detection tool for a review of textual similarity and detection of possible plagiarism. In doing so, students will allow their work to be included as source documents in the tool's reference database, where they will be used solely for the purpose of detecting plagiarism. The terms that apply to the University's use of this tool are described on the Centre for Teaching Support & Innovation web site: https://uoft.me/pdt-faq.

ACCESSIBILITY NEEDS:
Students with diverse learning styles and needs are welcome in CHM 343H. The University of Toronto is committed to accessibility: if you require accommodations for a disability, or have any other accessibility concerns about the course, please contact Accessibility Services as soon as possible. If possible, please submit your accessibility letter at the beginning of the course and not immediately before laboratory report or assignment is due.

ACCOMMODATIONS FOR RELIGIOUS OBSERVANCES:
Following the University's policies, reasonable accommodations will be made for students who observe religious holy days that coincide with the due date/time of an assignment, class or laboratory session. Students must inform the instructor **before** the assignment date to arrange accommodations.

ADDITIONAL SERVICES & SUPPORT:
The following are some important links to help you with academic and/or technical service and support:

- general student services and resources at Student Life
- full library service through University of Toronto Libraries
- resources on conducting online research through University Libraries Research
- resources on academic support from the Academic Success Centre
- learner support at the Writing Centre
- information for Technical Support/Quercus Support

ACKNOWLEDGEMENT OF TRADITIONAL LANDS:
We wish to acknowledge this land on which the University of Toronto operates. For thousands of years, it has been the traditional land of the Huron-Wendat, the Seneca and, most recently, the Mississaugas of the Credit River. Today, this meeting place is still the home to many Indigenous people from across Turtle Island and we are grateful to have the opportunity to work on this land.