

CHM 343H: ORGANIC SYNTHESIS TECHNIQUES Winter 2023 Course Syllabus

I TEACHING TEAM



INSTRUCTOR

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LABORATORY & COURSE COORDINATOR

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II COURSE OVERVIEW

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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 <u>Focus in Green</u> <u>Chemistry</u>, green chemistry decision-making is a central theme of both the class and laboratory components. CHM 343H builds extensively on material discussed in prerequisite courses (CHM 247H or CHM 249H), and **a thorough understanding of second-year 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 Yudin, Professor Dicks and the laboratory teaching assistants (TAs).

STUDENT LEARNING OUTCOMES:

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

- articulate 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
- basic NMR and IR spectroscopy of organic molecules
- stereochemistry of organic compounds (stereocentres, *R*, *S*, *E*, *Z* configurations, optical activity, *meso* compounds etc.)

- structure and reactivity of alkenes and alkyl halides
- aromaticity
- chemistry of alkenes and alkynes
- aromatic reactivity
- amines
- aldehydes and ketones
- carboxylic acids and their derivatives
- enolate chemistry

REFERENCE MATERIAL:

A general and very useful textbook for synthetic organic chemistry is <u>Organic Chemistry</u> (Second Edn.) by Clayden, Greeves and Warren (Oxford University Press). In addition, a highly recommended e-book regarding organic practical techniques is <u>The Synthetic Organic Chemists Companion</u> (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, "<u>Not Voodoo": Demystifying</u> <u>Synthetic Organic Chemistry Laboratory Techniques</u> 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 9th January.** An announcement will be made if the delivery mode of any or all instructional components needs to change due to the ongoing COVID-19 pandemic. Laboratories are scheduled to run in-person on Monday and Tuesday mornings, starting during the week of Monday 16th January.

CLASSES:

Classes will be offered in-person ONLY throughout the semester on MW from 3–4 p.m. in room LM 158 (classes will not be recorded). Please come prepared by having printed out the class notes posted on Quercus in advance. 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, metathesis)
- 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 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 an anti-depressant; and (ii) a sunscreen analog (featuring organocatalysis 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 conditions of phase-transfer catalysis; 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 Anti-Depressant *via* Amine Acylation: Synthesis of Moclobemide (Manerix[®]) (16th/17th January)
- 2. **Experiment 2:** The Sunscreen Cup (Part 1): Aqueous Methylation of 4-Hydroxybenzaldehyde Featuring Phase-Transfer Catalysis (23rd/24th January)
- 3. The Sunscreen Cup (Part 2): Organocatalysis in Action: Verley-Doebner Modification of the Knoevenagel Condensation (30th/31st January)
- 4. The Sunscreen Cup (Part 3): Final Synthesis of an Ultra-Violet Light Absorber (6th/7th February)
- 5. *Experiment 3*: A "Plan-Your-Own" Catalytic Alcohol Oxidation (13th/14th February)

WINTER READING WEEK: 20th – 24th FEBRUARY

- 6. **Experiment 4:** Environmentally Friendly Palladium Catalysis in Organic Synthesis: A Sonogashira Reaction (27th/28th February)
- 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) (6th/7th March).
- 8. Asymmetric Organocatalysis (Part 2) & Optimizing an Aqueous Catalytic Cross-Coupling Reaction to Synthesize a Biaryl NSAID Analog (Part 2) (13th/14th March).
- 9. Assessing the Sustainability of a Buchwald-Hartwig Cross-Coupling in Synthesizing Industrially Relevant Compounds (Future Leaders in Green Chemistry Assignment Practical Work) (20th/21st March)
- 10. *Experiment 7*: A "Design-Your-Own" Multi-Step Synthesis (1) (27th/28th March)
- 11. A "Design-Your-Own" Multi-Step Synthesis (2) Locker Clean-Up & Check-Out (3rd/4th April)

More information about the practical component of the course will be discussed during introductory workshops held during the mornings of Monday 9th/Tuesday 10th January.

IMPORTANT WINTER 2023 SESSIONAL DATES:

First Day of S classes: Monday 9th January Family Day: Monday 20th February Winter Reading Week (no classes): Monday 20th – Friday 24th February Last Day to Drop S Courses: Sunday 19th March Last Day of S classes: Thursday 6th April Good Friday (no classes or final examination/assessments): Friday 7th April April Final Examination Period: Tuesday 11th – Friday 28th April

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 written laboratory reports (reports have 10% deducted per day late to a maximum of two days).

2. Term Test (10% or 15%**, in-person, Wednesday 15th February, 3:10–4 p.m., 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 on Wednesday 15th February: the proposal is due by 11:59 p.m. on Monday 27th 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 early March to explaining the nature of this assignment. The assignment is due by 11:59 p.m. on Wednesday 5th April (10% deducted per day late to a maximum of two days).

5. Final Examination (25% or 20%^{**}, in-person, April final examination period, Tuesday 11th – Friday 28th 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: <u>q.utoronto.ca</u> (in your Quercus Dashboard, click on "CHM 343H Winter 2023").
 Please check the Quercus course website regularly for:
 - general course information
 - all specific laboratory information
 - class notes

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- 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:

 You send it from your utoronto.ca account;
 You identify yourself in the email subject as a student in CHM 343H and include your name and University of Toronto student ID number;
 No attachments are sent, unless official university correspondence is being forwarded (e.g., a letter detailing academic accommodations or a screenshot of an ACORN absence declaration);
 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.

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 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. Students who are absent from class for any reason (e.g., COVID-19 illness, other illness or injury, family situation) and who require consideration for missed academic work must report their absence through the online absence declaration. The declaration is available on ACORN under the "Profile and Settings" menu. A student who misses a laboratory session or the scheduled term test must additionally contact Professor Dicks via email with a screenshot of their ACORN absence declaration (see information on p. 1) WITHIN ONE WEEK to discuss their situation. This is a requirement to receive consideration for the missed test or laboratory session.

VI TECHNOLOGY REQUIREMENTS

• This course requires the use of computers, and technical issues are always possible. When working on a piece of academic work, 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 hard-drive failures, corrupted files, lost computers, etc.

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 <u>www.academicintegrity.utoronto.ca</u>).

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: <u>https://uoft.me/pdt-faq</u>.

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 <u>Accessibility Services</u> 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 <u>Student Life</u>
- full library service through <u>University of Toronto Libraries</u>
- resources on conducting online research through **<u>University Libraries Research</u>**
- resources on academic support from the <u>Academic Success Centre</u>
- learner support at the <u>Writing Centre</u>
- information for <u>Technical Support/Quercus Support</u>

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.