Chemistry
UNIVERSITY OF TORONTO

CHM 343H: ORGANIC SYNTHESIS TECHNIQUES

Winter 2022 Course Syllabus

I TEACHING TEAM

INSTRUCTOR
Name: Professor Andrei K. Yudin
Email: andrei.yudin@utoronto.ca
Research: https://sites.chem.utoronto.ca/yudinlab/content/andrei-yudin
Office: Davenport Building: DB 362
Student hours: to be announced on Quercus

LABORATORY & COURSE COORDINATOR
Name: Professor Andrew P. Dicks
Email: andrew.dicks@utoronto.ca
Research: chemistry.utoronto.ca/people/directories/all-faculty/andrew-p-dicks
Office: Lash Miller: LM 118
Student hours: to be announced on Quercus

TEACHING ASSISTANTS

Monday Laboratories:

Name: Joshua Graham (Demo. Gp. 11)
Email: joshm.graham@mail.utoronto.ca

Name: Weike Liang (Demo. Gp. 12)
Email: weike.liang@mail.utoronto.ca

Tuesday Laboratories:

Name: Kenneth Tran (Demo. Gp. 21)
Email: kenneth.tran@mail.utoronto.ca

Name: Andrew Durant (Demo. Gp. 22)
Email: andrew.durant@mail.utoronto.ca

NMR Demonstrator:

Name: Yuju Kim
Email: yuju.kim@mail.utoronto.ca

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 one course required as part of a 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 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 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 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 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 laboratory reports 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). CHM 343H is itself a prerequisite course for CHM 441H (Spectroscopic Analysis in Organic Chemistry).

Specific Knowledge & Concepts 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

Material from CHM 342H (Modern Organic Synthesis) and CHM 348H (Organic Reaction Mechanisms) is also useful preparation, but it is ***not*** assumed for this course.

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 i*s a very useful website for experimental and laboratory information on organic synthesis: http://chem.chem.rochester.edu/~nvd.

III HOW THE COURSE IS ORGANIZED

OVERVIEW:
CHM 343H has two instructional components – classes and laboratories – as well as a course discussion board. The classes will be delivered online through Zoom from Monday 10th – Friday 28th January inclusive, in keeping with guidance provided by the University (https://people.utoronto.ca/memos/limiting-the-spread-of-covid-19-omicron-variant-immediate-steps). As of 31st January, the intent is to offer in-person classes for the remainder of the Winter 2022 semester, *during which time you are expected to attend each class in-person*. Whether in-person or online, 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. Laboratories are scheduled to run in-person on Monday and Tuesday mornings, starting during the week of Monday 31st January.

CLASSES:
From 10th – 28th January inclusive, classes will be delivered online on MW from 3–4 p.m. Should in-person classes be possible from 31st January onwards, they will be held in room SS 1083. Please 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 online/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. They importantly 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
- a laboratory practical examination focused around a rudimentary reaction life-cycle analysis

The planned schedule of experimental work (spread over nine weeks) is as follows:

1. Locker Check-In & *Experiment 1*: Preparation of an Anti-Depressant via Amine Acylation: Synthesis of Moclobemide (Manerix®) (31st January/1st February)

2. *Experiment 2*: The Sunscreen Cup (Part 1): Aqueous Methylation of 4-Hydroxybenzaldehyde Featuring Phase-Transfer Catalysis (7th/8th February)

3. The Sunscreen Cup (Part 2): Organocatalysis in Action: Verley-Doebner Modification of the Knoevenagel Condensation (14th/15th February)

4. The Sunscreen Cup (Part 3): Final Synthesis of an Ultra-Violet Light Absorber (28th February/1st March)

5. *Experiment 3*: A "Plan-Your-Own" Catalytic Alcohol Oxidation (7th/8th March)

6. Assessing the Sustainability of a Buchwald-Hartwig Cross-Coupling in Synthesizing Industrially-Relevant Compounds ("Future Leaders in Green Chemistry" Assignment Practical Work) (14th/15th March)

7. *Experiment 4*: A "Design-Your-Own" Multi-Step Synthesis (1) (21st/22nd March)

8. A "Design-Your-Own" Multi-Step Synthesis (2) (28th/29th March)

9. Laboratory Examination, Locker Clean-Up & Check-Out (4th/5th April)

More information about the practical component of the course will be discussed in online introductory workshops held during the mornings of Monday 24th/Tuesday 25th January.

COURSE DISCUSSION BOARD:
In addition to offering student hours, we will be using the free Ed discussion platform that facilitates online questions and answers. Information on how to join the platform will be made available as an announcement at the Quercus course website. You are strongly encouraged to ask your content questions on this discussion board where all students can benefit. **The teaching team will be monitoring the discussion board and providing input as needed, although we expect students to be helping each other as much as possible.** Please note that posting assignment/laboratory report questions and/or sharing solutions to these questions is in violation of the University of Toronto's Code of Behaviour on Academic Matters (see the Academic Integrity section of the syllabus for more details).

IMPORTANT WINTER 2022 SESSIONAL DATES:
First Day of S classes: Monday 10th January
Family Day: Monday 21st February
Winter Reading Week (no classes): Monday 21st – Friday 25th February
Last Day to Drop S Courses: Monday 14th March
Last Day of S classes: Friday 8th April
April Final Assessment Period: Monday 11th – Friday 29th 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 reports), in one term test, in two assignments, and in a final examination:

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

ASSESSMENT DATES & MARK BREAKDOWN:
1. Term Test (10% or 15%*, in-person, Wednesday 16th February, 3:10–4 p.m., room EX 310, written during regularly-scheduled class time). Note: *this assessment may be offered completely online if in-person testing is not possible*.

2. "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 16th February: the proposal is due by 11:59 p.m. on Monday 28th February (10% deducted per day late to a maximum of two days).

3. "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 Tuesday 29th March (10% deducted per day late to a maximum of two days).

4. Final Examination (25% or 20%*, in-person, April final assessment period, Monday 11th – Friday 29th April). Note: *this assessment may be offered completely online if in-person testing is not possible*.

5. Laboratory** (45%, throughout semester). Quality of practical work/results/submitted products and written laboratory reports (reports have 10% deducted per day late to a maximum of two days).

*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.

****the practical skills acquired in CHM 343H 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 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.**

V IMPORTANT COURSE POLICIES

- Each member of this course is expected to maintain a:
    - professional and respectful attitude during all course activities, including classes, laboratories, and online activity. A face mask is required to be worn for any and all in-person activities: https://governingcouncil.utoronto.ca/secretariat/policies/face-masks-policy
    - 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 2022"). **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); (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.

- 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 (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 or the course discussion board) 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.