CHEM 3401 Intermediate Organic Chemistry Syllabus

Department of Chemistry

CRN20490 Winter 2026

Dalhousie University operates in the unceded territories of the Mi'kmaw, Wolastoqey, and Peskotomuhkati Peoples. These sovereign nations hold inherent rights as the original peoples of these lands, and we each carry collective obligations under the Peace and Friendship Treaties. Section 35 of the Constitution Act, 1982, recognizes and affirms Aboriginal and Treaty rights in Canada.

We recognize that African Nova Scotians are a distinct people whose histories, legacies, and contributions have enriched the part of Mi'kma'ki known as Nova Scotia for over 400 years.

Course Instructor(s)

Name	Email	Office Hours
Alex Speed	aspeed@dal.ca	By Request
Reinaldo Moya-Barrios	rbarrios@dal.ca	Thursdays and Fridays, 12:30-1:20 pm, Room 1053

Course Description

Topics presented include aromatics, heterocycles, amines, enolate anions and other methods for forming C-C bonds, concerted reactions, carbohydrates and some heteroatom chemistry. There is a continuing emphasis on the principles of mechanistic organic chemistry. Students work independently in the laboratory on the preparation of organic compounds.

Course Prerequisites

Required Course: CHEM 2402.03, minimum grade: C+.

Organic chemistry involves both a great deal of memorization and understanding. Much like a language, you must possess a memorized vocabulary (reactions), but also a correct understanding of syntax and grammar (thinking mechanistically, and knowing how and when to apply reactions) to have success in this course. You are expected to have a **FLUENT** command and understanding of the material from CHEM 2401 and 2402. Being able to draw correct Lewis structures, produce legible structures with reasonable geometry, evaluate resonance

contributors and draw curved arrow mechanisms will be necessary for success in this course. Organic synthesis is a cumulative discipline, and it is expected that you have retained knowledge of reactions and concepts covered in preceding courses. You will be both explicitly and implicitly tested on material covered in CHEM 2401/2402. A separate list of concepts that were covered in CHEM 2401/2402, and the corresponding page/chapter numbers in this course's textbook is made available on Brightspace.

Student Resources

Office hours can be made by appointment with Dr. Speed, through e-mail.

Course Structure

Course Delivery

The course will be delivered in person. Missed lectures will not be repeated, however notes will be made available after lecture on Brightspace.

Lectures

M,W,F from 10:35–11:25 in Room 221C of the Sir James Dunn Building (the Physics Building).

Laboratories

R,F from 13:35–17:25 in Rooms 121-125P of the Chemistry Building.

Please contact Dr. Moya-Barrios for all matters regarding the laboratory. Lab sessions will be held in the Chemistry Podium, Rooms 121-125P, at your scheduled times on Thursday and Fridays. ***Labs start on Friday January 9.***

Course Materials

- *"Organic Chemistry"* by Jonathan Clayden, Nick Greeves, Stuart Warren. Oxford University Press, 2nd Edition, 2012. This book is available at the bookstore and will be the textbook I provide readings from.
- I encourage using molecular models to understand conformation and selectivity, and these will be permitted during examinations, however they are not required.
- Non-graded practice problems and their solutions will be made available on a regular basis. Successful study habits in organic chemistry typically involve actively, frequently, and repetitively practicing drawing mechanisms for the reactions under study, rather than simply reviewing the mechanism and attempting to reproduce the mechanism for the first time under evaluation.

In Person Laboratory Materials

- CHEM 3401 Laboratory Manual from academic year 2025-2026.
- Hard-covered laboratory notebook
- Safety glasses (prescription glasses that are not safety glasses are not sufficient)
- Approved lab coat
- All pertinent safety training (WHMIS 2015, and the Dalhousie Laboratory Safety Course), must be completed before the deadlines listed in the CHEM 3401 Laboratory Manual. If you have recently completed CHEM 2401/2402, you have likely taken the WHMIS course, in that case simply upload the proof of completion to the CHEM 3401 Brightspace site by the due date.

Useful Websites

Various websites are available containing information that complements that presented in the course, or may be of use in assignments.

- **Primary literature:**
  There are many journals. A small set of important chemistry journals are shown below. To access these from home, the URL must be accessed through Dalhousie's library proxy server. See: https://libraries.dal.ca/help/remote-access.html

  American Chemical Society Journals: http://pubs.acs.org

  Royal Society of Chemistry Journals: http://www.rsc.org/journals-books-databases/

  Angewandte Chemie International Edition: (German Chemical Society): http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)1521-3773

  Scifinder Scholar is a useful tool for searching the chemical literature

  Dalhousie Scifinder Scholar: http://libraries.dal.ca/research/sciences_research/sfs.html

- **Databases**
  Aldrich: Chemical Catalogue, with physical properties and select NMR spectra of compounds http://www.sigmaaldrich.com

  SDBS: Database of NMR, IR, MS spectra for many compounds. http://sdbs.db.aist.go.jp/sdbs/cgi-bin/direct_frame_top.cgi

  Bordwell pKa database: Extensive database of pKas

  https://organicchemistrydata.org/hansreich/resources/pka/

Assessment

Component	Weight (% of final grade)		Date
Two tests	40 %	(20 % each)	W, Feb 11th; M, Mar 23rd 16 29
Two Assignments	5 %	(2.5 % each)	F, Jan 16th; W, Mar 4th
Final exam	35 %		(Scheduled by Registrar)
Laboratory	20 %		(See Brightspace for schedules and due dates)

Conversion of numerical grades to final letter grades follows the
Dalhousie Grade Scale

A+ (90-100)	B+ (77-79)	C+ (65-69)	D (50-54)
A (85-89)	B (73-76)	C (60-64)	F (0-49)
A- (80-84)	B- (70-72)	C- (55-59)	

A passing grade (10/20) is required in the laboratory section to pass the class. The assignments will be take-home assignments based on course material. I intend these to provide early feedback with a relatively low value to identify concepts you may struggle with in advance of the tests. Accordingly, you will obtain maximum benefit from these if you work your own, rather than in collaboration.

Course Policies on Missed or Late Academic Requirements

Brief Absences: Attendance and participation are not components of evaluation in the lecture part of this course, so absences outside of tests or exams do not need to be accounted for. You will still be responsible for material in any lecture you missed. If you are ill or otherwise experiencing a personal emergency at the time of a midterm test, e-mail me when convenient to inform me of the situation, and fill out a Student Declaration of Absence form (available at Brightspace) at an appropriate time. Many circumstances can count as personal emergencies, and I am happy to help you to the best of my ability in accommodating unexpected life circumstances that may take priority over this course for you. While I do not generally offer make-ups for one missed midterm, in the case of a missed midterm due to illness or another prearranged situation, the weighting of the final exam will change to make up the missing marks. **Longer Term Absence:** In the case of situations that require a longer absence, please contact me to arrange accommodations to keep up with course material. The declaration of Absence form may only be used twice per class per semester, and accommodation of longer-term illnesses is best handled through involvement of the Assistant Dean (Student Affairs), Patricia Laws, from the Faculty of Science. **Missed Final Exam:** Students who are ill for the final exam and produce an appropriate Declaration of Absence will have an opportunity to write a make-up final exam. Other absences from the final exam due to personal emergency will be accommodated at my discretion. **Accommodation:** The Student Declaration of Absence Form applies to acute illness and is not intended as a replacement for seeking accommodation if you have learning differences that affect your ability to take an evaluation. Dalhousie provides expertise in this area: to arrange accommodations for tests or exams through the Advising and Access Services Centre. If you feel you require any assistance deciding if you need help, please let me know, and I will offer advice. **Late Assignments:** Late assignments will not be accepted after graded assignments have

been returned to the class.

Course Policies related to Academic Integrity

The graded assignments are intended to evaluate **your** knowledge in a low-stakes format, so you should not collaborate on them, or use external resources such as SciFinder or ChatGPT (or other large language model AIs) to assist you with them.

Learning Objectives

Organic synthesis allows the synthesis of molecules that broadly impact our lives through application in healthcare, materials science, food processing and fundamental research. Organic chemistry has the reputation of being a difficult topic, however the degree of difficulty depends on how you approach the subject. While the study of organic chemistry does involve substantial memorization, you will gain the most understanding with the least amount effort from this course by seeking to understand trends in the chemistry you see, rather than treating each reaction as an isolated concept to be memorized. Appreciating trends and patterns gives you the maximum ability to apply what you have learned to predict the outcome of reactions that are new, either to you, or to science.

In CHEM 3401, we will examine some of the most important carbon-carbon bond forming reactions, including reactions on aromatic heterocycles. An overview of chemistry for introduction and manipulation of common heteroatoms is provided. Simple stereochemical considerations are introduced. After successful completion of the course, students will be able to formulate multi-step syntheses of molecules of moderate complexity, containing multiple functional groups, with some knowledge of how to develop strategy based on considerations of reactivity.

Course Content

Part 1: Aromatic Chemistry
Electrophilic Aromatic Chemistry (Chapter 21)
Start with Clayden Chapter 21, EAS
EAS Mechanism (Chapter 21, P 474-475)
Recap electrophilic substitutions, particularly halogenation:
EAS Summary table (Chapter 21 P 478)
Ortho/Para Selectivity (Chapter 21, P479)
Meta Selectivity (Chapter 21, P486)
Summary of Directing and activating effects (Chapter 21, P491)
Strategy, ie transforming a directing group type, acylation/deoxygenation, nitro reduction, etc (Chapter 21, P492-P494, Chapter 24, P565-P568)
Indanone synthesis, recap carboxylate transformations. Tetralin synthesis described (Chapter 21, P494)
Competition between different directing groups, ie sulfa drugs, benzodiazepines, Tylenol (Chapter 21, P 491)
Summary (Chapter 21, P495-P497)

Conjugate addition and S_NAr (Chapter 22)
Addition/Elimination/ Nucleophilic Aromatic Substitution (S_NAr) (Chapter 22, P514-520)
Sandmeyer (Chapter 21, P 495, Chapter 22, P520-523)
Azo dyes
Benzyne (Chapter 22, P522-P525)

Carbanion Chemistry (Chapter 9)
Grignard/Organolithium overview (Chapter 9, P184-P186)
Directed metalation (Chapter 9, P186-188, Chapter 24, P563-564)
Lithium halogen exchange (Chapter 9, P188-189)
Magnesium halogen exchange
Transmetallation (Chapter 9, P189)

Heterocycle Reactions (Chapter 29)
Aromaticity of heterocycles/ overview (Chapter 29, P723-726, Chapter 29, P753-755))
Reactions on electron poor pyridines (Chapter 29, P727-729)
Activation of pyridines for EAS (Chapter 29, P729-P731)
Boekelheide reaction (Chapter 29, P731)
Reactions on electron rich heterocycles, including formylation (Chapter 29, P733-737)
Vilsmeier Reaction (Chapter 29, P733-734)
Raney Nickel desulfurization (Chapter 29, P737)
Metalation of heterocycles (Chapter 29, P737-738)
Benzo-fused heterocycles (indole, benzothiophene) (Chapter 29, P745-P747)

Organometallic Chemistry (Chapter 40)
Fundamental organometallic reactions (Chapter 40, P1073-1079)
Triflates as pseudohalides (Chapter 40, P1079)
Heck, Cyclic Heck (Chapter 40, P1079-1082)
Transmetallation (Chapter 40, P1083)
Cross-Coupling (Chapter 40, P1082)
Negishi (Chapter 40, P1083-P1084)
Stille (Chapter 40, P1084)
Suzuki (Chapter 40, P1085-P1087)
Sonogashira (Chapter 40, P1087-P1088)
Tsuji-Trost (Chapter 40, P1088-P1091)
Buchwald-Hartwig Amination (BHA) (Chapter 40, P1092-P1096)
Comparison of BHA and S_NAr (Chapter 40, P1095)
Pauson Khand
Wacker oxidation (Chapter 40, P1096-P1097)
Olefin Metathesis (Chapter 40, P1099-P1100)

Part 2: Chemoselectivity, Synthesis Strategy, and Protecting Groups
Oxidation State Interconversion
Refresher on carboxylate chemistry reactivity (Chapter 10, P197-P216)
Overview of Chemoselectivity/ Regioselectivity Chapters 23/24
Chemoselectivity in reduction/ tetrahedral intermediates: $LiAlH_4$/$NaBH_4$/$LiBH_4$/Red-Al/Selectride/Superhydride vs BH_3, DiBAlH. (Chapter 23, P530-534) Summary table P534
Weinreb synthesis (Chapter 10, P218-P220)

Alcohol to carbonyl oxidation (Chapter 23, P544-P546, Chapter 27, P667-668)

Functional Group Interconversion
Wittig/HWE (Chapter 11, P237-238, Chapter 23, P689-P693)
Hydroboration (Chapter 19, P446-447)
Enamines/ imines (Chapter 11, P229-P237)
Reductive amination (Chapter 11, P234-P236, Chapter 23, P538)
Ellman auxiliary

Protecting Groups (Chapter 23)
DCC (Chapter 29, P747-748)
Protecting groups- Need for orthogonal protecting groups
Protecting groups for carbonyls: Acetals (Chapter 23, P548-P549)
Protecting groups for alcohols: TBS, benzyl, PMB, MOM, THP, esters (Chapter 23, P549-P553)
Selective desilylation
Protecting groups for amines: Boc and FMOC (Chapter 23, P557-560)
Protecting group overview (Chapter 23, P560)
Synthetic Strategy, retrosynthetic analysis, synthesis planning (Chapter 28, P694)

Part 3: Carbonyl Chemistry (And conjugate chemistry)
pKa overview
Alkylation and conjugate addition reactions (Chapter 25)
Common Electrophiles (Chapter 25, P587)
Strategies for weak vs strong bases in carbonyl chemistry (Chapter 25, P584-P585)
Nitrile and Nitroalkane alkylation (Chapter 25, P585-P587)
Enolate alkylation (Chapter 25, P588)
Enamine alkylation (Chapter 25, P591-P594)
Beta dicarbonyls (Chapter 25, P596-598)
Regiocontrol in Ketone Alkylation (Chapter 25, P598-P601)
Conjuagate enolate formation (Chapter 25, P602-P605)
Conjugate addition of carbon (Chapter 25, P605-P608)
Stork-Danheiser sequence

Carbonyl/ carboxylate groups as electrophiles (Chapter 26)
Aldol condensation (Chapter 26, P614-P618)
Crossed Aldol condensation (Chapter 26, P618-P623)
Nitro aldol (Chapter 26, P623-P624)
Aldol addition with specific enolates (Chapter 26, P624-P636)
Robinson Annulation (Chapter 26, P636-P640)
Claisen condensation (Chapter 26, P640-P648)

Heterocycle Synthesis from carbonyl compounds (Chapter 30)
Overview (Chapter 30, P757)
Condensation reactions to make 5-membered heterocycles (Chapter 30, P758-763)
Knorr Pyrrole Synthesis (Chapter 30, P762)
Condensation reactions to make 6-membered heterocycles (Chapter 30, P765-767)
Hantzsch Pyridine Synthesis (Chapter 30, P763-765)
Fischer Indole Synthesis (Chapter 30, P775-779)

Summary (Chapter 30, P785-P788)

Part 4: Pericyclic Chemistry (Chapter 34, 35)
Diels-Alder introduction (Chapter 34, P877-P880)
s-Cis/s-trans to explain diene reactivity (Chapter 34, P880)
concertedness of Diels-Alder reactions (Chapter 34, P880-884)
FMO theory for Diels-Alder reaction (Chapter 34, P885-888)
Lewis Acids for catalysis of Diels-Alder (Chapter 34, P891)
regioselectivity of Diels-Alder reactions (Chapter 34, P889-891)
endo/exo selectivity in the Diels-Alder (Chapter 34, P884)
Cope/ Claisen introduction (Chapter 35, P909-P913)
The Claisen/ vinyl ether problem
Ireland Claisen (Chapter 35, P914)
The Cope and oxy-Cope (Chapter 35, P914-916)
The anionic oxy-Cope (Chapter 35, P914)

Part 5: Sulfur/Phosphorus/Silicon, Boron Chemistry (Chapter 27)
S alkylation (Chapter 27, P658-P660)
Mustard/ Anchimeric effect (Chapter 27, P664)
Sulfoxide/Greico elimination (Chapter 27, P685-P686)
Julia olefination (Chapter 27, P686-P688)
Pummerer, redox
Corey Chaykovsky (Chapter 27, P664-P667)
Appel Reaction
Brook rearrangement
Peterson olefination (Chapter 27, P671, P688)
Sakurai reaction (Chapter 27, P672-P677)
Boron enolates (Chapter 33, P871)
Allylboration
Matteson homologation

Week	Date	Lesson Topic(s)
1	Jan 7th, Jan 9th	Electrophilic Aromatic Substitution
2	Jan 12th, Jan 14th, Jan 16th	Aromatic functional group interconversions, nucleophilic aromatic substutition, Sandmeyer, benzyne
3	Jan 19th, Jan 21st, Jan 23rd	Metalation, heterocycles, pyridine reactions, thiophene and furan
4	Jan 26th, Jan 28th, Jan 30th	Transition metal cross-coupling, olefin metathesis
5	Feb 2nd, Feb 4th	Tetrahedral intermediates, chemoselectivity in reduction

6	Feb 9th, **Feb 11th**, Feb 13th	**Test 1 on Feb 11th**, Oxidation reactions, olefination
7		Reading Week
8	Feb 23rd, Feb 25th, Feb 27th	Wittig reaction, Horner-Wadsworth-Emmons reaction, hydroboration
9	March 2nd, 4th, 6th	Reductive amination, enolate alkylation, nitro-alkylation, beta carbonyl chemistry
10	March 9th, 11th, 13th	Enolization selectivity, conjugate Addition, the aldol reaction
11	March 16th, 18th, 20th	Crossed and direct aldols, Claisen condensation, Robinson annulation
12	**March 23rd**, 25th, 27th	**Test 2 on March 23rd**, Synthesis of heterocycles from carbonyls, Fischer indole synthesis
13	March 30th, April 1st	The Diels Alder reaction, Cope and Claisen rearrangements
14	April 6th, 8th, 9th	More examples of sulfur, silicon, phosphorus and boron in organic synthesis
		Exam Period Begins April 11th, Exam Date TBD By Registrar

University Policies and Statements

Recognition of Mi'kmaq Territory

Dalhousie University would like to acknowledge that the University is on Traditional Mi'kmaq Territory. The Elders in Residence program provides students with access to First Nations elders for guidance, counsel, and support. Visit or e-mail the Indigenous Student Centre at 1321 Edward St or elders@dal.ca. Additional information regarding Mi'kmaq and Indigenous Relations (including the Elders in Residence program, Land Acknowledgements, Understanding Our Roots, and much more) can be found at: https://www.dal.ca/about/mission-vision-values/mikmaq-indigenous-relations.html

Internationalization

At Dalhousie, 'thinking and acting globally' enhances the quality and impact of education, supporting learning that is "interdisciplinary, cross-cultural, global in reach, and orientated toward solving problems that extend across national borders." Additional internationalization information can be found at: https://www.dal.ca/about/mission-vision-values/global-relations.html

Academic Integrity

At Dalhousie University, we are guided in all our work by the values of academic integrity: honesty, trust, fairness, responsibility, and respect. As a student, you are required to demonstrate these values in all the work you do. The University provides policies and procedures that every member of the university community is required to follow to ensure academic integrity. Additional academic integrity information can be found at: https://www.dal.ca/dept/university_secretariat/academic-integrity.html

Accessibility

The Student Accessibility Centre is Dalhousie's centre of expertise for matters related to student accessibility and accommodation. If there are aspects of the design, instruction, and/or experiences within this course (online or in-person) that result in barriers to your inclusion, please contact the Student Accessibility Centre (https://www.dal.ca/campus_life/academic-support/accessibility.html) for all courses offered by Dalhousie with the exception of Truro. For courses offered by the Faculty of Agriculture, please contact the Student Success Centre in Truro (https://www.dal.ca/campus_life/ssc.html).

Conduct in the Classroom – Culture of Respect

Substantial and constructive dialogue on challenging issues is an important part of academic inquiry and exchange. It requires willingness to listen and tolerance of opposing points of view. Consideration of individual differences and alternative viewpoints is required of all class members, towards each other, towards instructors, and towards guest speakers. While expressions of differing perspectives are welcome and encouraged, the words and language used should remain within acceptable bounds of civility and respect.

Diversity and Inclusion – Culture of Respect

Every person at Dalhousie has a right to be respected and safe. We believe inclusiveness is fundamental to education. We stand for equality. Dalhousie is strengthened in our diversity. We are a respectful and inclusive community. We are committed to being a place where everyone feels welcome and supported, which is why our Strategic Direction prioritizes fostering a culture of diversity and inclusiveness (Strategic Priority 5.2). Additional diversity and inclusion information can be found at: https://www.dal.ca/about/mission-vision-values/equity-diversity-inclusion-and-accessibility/about-office-equity-inclusion.html

Student Code of Conduct

Everyone at Dalhousie is expected to treat others with dignity and respect. The Code of Student Conduct allows Dalhousie to take disciplinary action if students don't follow this community expectation. When appropriate, violations of the code can be resolved in a reasonable and informal manner - perhaps through a restorative justice process. If an informal resolution can't be reached, or would be inappropriate, procedures exist for formal dispute resolution. The full Code of Student Conduct can be found at: https://www.dal.ca/content/dam/www/about/leadership-and-governance/governing-bodies/code-student-conduct.pdf

Fair Dealing Policy

The Dalhousie University Fair Dealing Policy provides guidance for the limited use of copyright protected material without the risk of infringement and without having to seek the permission of copyright owners. It is intended to provide a balance between the rights of creators and the rights of users at Dalhousie. Additional information regarding the Fair Dealing Policy can be found at: https://www.dal.ca/content/dam/www/about/leadership-and-governance/university-policies/fair-dealing-policy.pdf

Student Use of Course Materials

Course materials are designed for use as part of this course at Dalhousie University and are the property of the instructor unless otherwise stated. Third party copyrighted materials (such as books, journal articles, music, videos, etc.) have either been licensed for use in this course or fall under an exception or limitation in Canadian Copyright law. Copying this course material for distribution (e.g. uploading to a commercial third-party website) may lead to a violation of Copyright law.