# CHEM2420 Organic Chemistry II

The University of Toledo  
Department of Chemistry and Biochemistry  
College of Natural Sciences and Mathematics  
CRN: 11109 and CRN: 11111

<table>
<thead>
<tr>
<th>Instructor:</th>
<th>Dr. Zin-Min Tun</th>
<th>Class Location:</th>
<th>WO1205</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-Mail:</td>
<td><a href="mailto:zinmin.tun@utoledo.edu">zinmin.tun@utoledo.edu</a></td>
<td>Class Day/Time:</td>
<td>M &amp; W 5:30 – 6:50 pm</td>
</tr>
<tr>
<td>Office Hours:</td>
<td>M 12:00 – 1:00 pm; W &amp; Th 11:00 am – 1:00 pm</td>
<td>Credit Hours:</td>
<td>3 credit hours</td>
</tr>
<tr>
<td>Office:</td>
<td>BO2034</td>
<td>Term:</td>
<td>Spring, 2019</td>
</tr>
<tr>
<td>Phone:</td>
<td>419-530-4591</td>
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## REQUIRED INSTRUCTIONAL MATERIALS (TEXTS AND ANCILLARY MATERIALS)

**A. Required Materials:** “SAPLINGPLUS FOR ORG.CHEM (12 MONTHS)” through UT Barnes and Nobel Bookstore - $114.30. What it includes is:


- **Account for SAPLINGPLUS Learning:** please access SAPLINGPLUS Learning from Blackboard. The access code comes as part of the “SAPLINGPLUS FOR ORG.CHEM (12 MONTHS)” through UT Barnes and Nobel Bookstore

- **iClicker Cloud:** please install the iClicker Cloud APP (REEF) on your **cell-phone**. We will be using Clicker responses in class this year for points. This already comes as part of the “SAPLINGPLUS FOR ORG.CHEM (12 MONTHS)” through UT Barnes and Nobel Bookstore

**B. Recommended Materials:**


COURSE DESCRIPTION
CHEM2420, Organic Chemistry II, covers the second half of Organic Chemistry, which includes the structure and reactivity of organometallic compounds, radicals, aldehydes and ketones, carboxylic acids and their derivatives, enolates and related compounds, aromatic systems, amines and heterocyclic compounds. In addition, modern methods and techniques in organic structure elucidation (IR, $^1$H and $^{13}$C NMR spectroscopy, and mass spectrometry) will be introduced and discussed.

PREREQUISITES AND COREQUISITES
The prerequisite for this course is a C- in CHEM2410 (Organic Chemistry I). Students not satisfying the prerequisite will be dropped from the course. While it is not required, students are highly recommended to complete CHEM2460 or 2480 before the beginning of this course and take CHEM2470 or 2490 in the same semester.

COURSE STRUCTURE
Lecture:
- Lecture sessions are designed to clarify the concepts covered in this course and provide examples of what is expected of you.
- Attendance is expected and you are responsible for all material and problems covered in class.
- It is recommended that you read the text before the lecture.
- Lecture notes will be available on Blackboard for each chapter.
- Please be considerate of your fellow students during the lecture period. Disruptions of any kind will not be tolerated and may result in expulsion from the classroom.

Grades:
Homework:
There are two types of homework associated with this course: 1) SAPLINGPLUS Learning Homework which will count towards your grade; and 2) problems from the textbook at the end of each chapter which will not be handed in or graded.

SAPLINGPLUS Learning Homework:
12 homework assignments will be administered and graded. You WILL NEED to purchase an access code (Purchase “SAPLINGPLUS FOR ORG.CHEM (12 MONTHS)” through UT Barnes and Nobel Bookstore) and will NEED TO REGISTER with the correct Lecture class. A direct link from Blackboard to SAPLINGPLUS will be available via this course’s Blackboard site. These exercises are not timed, however, you will have unlimited tries with the loss of some credit for each try that is wrong before the due date. The start date/time and due date/time for each assignment can be found within the SAPLINGPLUS homework system. Please do your work well in advance of the due date. Do not wait until the last minute! Technical problems with your computer, SAPLINGPLUS, or your internet connection will not be grounds for an extension. You can log in at any time to complete or review your homework assignments. If you have any problems, send an email to support@saplinglearning.com explaining your issue.

Suggested Homework Problems: There are suggested homework problems assigned from the end-of-chapters in the textbook (in the syllabus). Completion and understanding of these problems will be a big step towards achieving a good grade in this course. It is recommended that you use the problems in the textbook for study and review in your efforts to master the material covered in each chapter. The chapter questions are not graded but as noted they are HIGHLY RECOMMENDED!
Blackboard:
- Blackboard is a course management system provided by the University of Toledo and can be accessed at https://blackboard.utdl.edu/. Your access code is your UTAD user name and password.
- You should consult the site regularly for news and announcements. Handouts, lecture notes, practice exams, and exam solutions will be posted. The system also permits you to check your grades at any time and to email your instructor or other students in the class.

Examinations:
The exam schedule is listed below. Make-up exams will not be given for any circumstance. Excused absences will be given only to students who miss a midterm exam under the conditions listed below. If an excuse is acceptable, your final course grade will be computed accordingly. The final exam cannot be excused. For all exams you must show a UT photo identification card*. You will not be permitted to have a cell phone on your desk.

* A UT photo identification card is mandatory in order for you to take the exam (http://www.utoledo.edu/orientation/new/StudentID.html).

- There will be three mid-term examinations (100 points each). Exams will be held during normal class periods (See course schedule in syllabus).
- The comprehensive ACS final exam (Chapters 1-23, 25, 200 points + 10 bonus points = 210 points total) will be administered in WO 1205 on Monday, April 29th, 5:00pm - 7:00 pm, the time scheduled by the University. The ACS final exam contains 70 multiple choice questions and each is worth three points.

Exam Absence Policies
Refer to UT Missed Class Policy (https://www.utoledo.edu/policies/academic/undergraduate/pdfs/3364-71-14-20Missed%20class%20policy.pdf). Students who will not be able to take an exam at the scheduled time due to an irresolvable conflict with a major responsibility must provide some written documentation to verify the conflict. This situation may occur for students on official university business, including athletes. Approval must be obtained before the scheduled test date.

Students who do not take an exam due to illness, car accident, and death in the family or similar extreme circumstance should inform their instructor of their difficulties within 24 hours of the exam. These difficulties must also be documented by a physician's note, an accident report, pastor’s note, etc. Contact information for the police department, pastor, etc. must be included on the note or report. In all other circumstances, a missed exam will result in a grade of 0. Exams cannot be excused for personal reasons. Examples of missing an exam due to personal issues include, but are not limited to: oversleeping, transportation problems, vacation plans, work schedule conflicts, child care issues, sick children, fire alarms in adjacent buildings, etc. Please plan accordingly.

iClicker Cloud (REEF):
Students will use an electronic device (cell-phones) to enter “real-time” in class responses to questions that are asked in lecture (questions will appear on the screen).

Communication:
You are urged to communicate with the instructor about any aspect of the course which concerns you or which might limit your success. We want you to be successful in this course, so let’s work together!
OVERVIEW OF COURSE GRADE ASSIGNMENT

Course Points:
The following is the distribution of possible points in the course:

- Sapling Homework Assignments: 150 pts (21.4%)
- Midterm Exams 3 @ 100 points each: 300 pts (42.9%)
- Comprehensive Final Exam: 200 pts (28.6%)
- iClicker Response and Attendance: 50 pts (7.1%)

Total: 700 pts (100%)

Midterm Grading
Midterm grading serves as a point in the term where the instructor of record may provide a midterm grade assessment and may identify any student who has never attended, has stopped attending, or who is not actively participating in the course. In addition, students may use midterm grade to help make a decision in regards to withdrawing from the course.

The U.S. Department of Education requires the University to document both active participation and satisfactory academic progress as part of the compliance with federal financial aid regulations. Students receiving Title IV Federal Aid funds are required to have regular attendance and satisfactory academic progress in their courses to receive federal aid.

Final Grading
Your final grades will be calculated based on a total of 700 points.

Grade Scale
These are the minimum percentages needed to receive the indicated grade:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>A</td>
<td>87%</td>
</tr>
<tr>
<td>A–</td>
<td>85%</td>
</tr>
<tr>
<td>B+</td>
<td>82%</td>
</tr>
<tr>
<td>B</td>
<td>75%</td>
</tr>
<tr>
<td>B–</td>
<td>73%</td>
</tr>
<tr>
<td>C+</td>
<td>70%</td>
</tr>
<tr>
<td>C</td>
<td>63%</td>
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<tr>
<td>D</td>
<td>52%</td>
</tr>
<tr>
<td>D–</td>
<td>50%</td>
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Drop, Withdrawal and Incomplete Grades:
- Course drop and withdrawal procedures have been set by the University faculty. Dropped courses do not appear on your transcript. The deadline for dropping is January 28th. If you are in a course after that date, there will be a grade on your transcript (A-F, W, or Incomplete).
- You may withdraw from the course and receive a grade of W. W’s do not affect your GPA. For both dropping the course or withdrawing you should go to the Registrar's Office in Rocket Hall. You do not need your instructor’s permission for either process. Please note that course registration changes might change your financial aid. The deadline for withdrawal is March 29th.
- If you drop or withdraw from this CHEM 2420, you must also drop/withdraw from the lab course CHEM 2470 because you need to know the lecture material to be in lab.
- A course grade of Incomplete is given only to those who have completed all but a small percentage of course requirements for an acceptable reason.

Academic Dishonesty:
The academic honesty policies, as stated in the 2013-2014 UT Catalogue will be STRICTLY ENFORCED. Any student found violating the UT academic honesty policies will be penalized in accordance with these policies. You should read the university’s policy on Academic Dishonesty found at http://www.utoledo.edu/catalog/2000catalog/admissions/academic_dishonesty.html. There is also an academic honesty policy for the Chemistry Department posted on Blackboard. The academic honesty policy for the Department will also be STRICTLY ENFORCED.
Chemistry Help Center:
The Chemistry Help Center, BO 2043, is where the teaching assistants hold their office hours so it is a great place to receive assistance. It is generally open all day Monday through Friday and evenings Monday through Thursday. A schedule will be posted on Blackboard early in the term. No appointment is necessary.

Tutoring support for all UT students is available through the Learning Enhancement Center located in the Carlson Library.

Recitation (CHEM 2440):
These sessions are a supplemental portion of the course. They are not required but are highly recommended. During these small classes the recitation leader will answer questions and get you to the board to work practice problems from the lecture text and the ACS study guide. You should go to recitation prepared, having worked or tried to work the assigned problems so bring your solved homework.

Special Needs:
If you have special needs with respect to your participation in this course, please make an appointment to discuss this matter with your instructor. The instructor will work with you and the Student Disability Services to make appropriate accommodations for your needs.

UNIVERSITY POLICIES
Policy Statement on Non-Discrimination on the basis of Disability (ADA). The University is an equal opportunity educational institution. Please read The University’s Policy Statement on Nondiscrimination on the Basis of Disability Americans with Disability Act Compliance.

ACADEMIC ACCOMMODATIONS
The University of Toledo is committed to providing equal access to education for all students. If you have a documented disability or you believe you have a disability and would like information regarding academic accommodations/adjustments in this course please contact the Student Disability Services Office.
## COURSE SCHEDULE

<table>
<thead>
<tr>
<th>Week</th>
<th>Dates</th>
<th>Chapter: Topic</th>
<th>Notes</th>
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| 1    | Jan 14 - Jan 16 | Introduction  
15: Benzene and Aromaticity                                               | 1/21 is MLK Day. Classes are cancelled.                                   |
| 2    | Jan 21 – Jan 23 | 15: Benzene and Aromaticity  
16: Electrophilic Attack on Derivatives of Benzene                  | Last day to Drop via the web is Mon 1/28                                |
| 3    | Jan 28 – Jan 30 | 16: Electrophilic Attack on Derivatives of Benzene  
17: Aldehydes and Ketones                                                  |                                                                      |
| 4    | Feb 4 – Feb 6  | 17: Aldehydes and Ketones                                                    |                                                                      |
| 5    | Feb 11 – Feb 13 | 18: Enols, Enolates, and the Aldol Condensation                             | Exam 1, Monday, 2/11, Ch 15 – 17                                       |
| 6    | Feb 18 – Feb 20 | 18: Enols, Enolates, and the Aldol Condensation  
19: Carboxylic Acids                                                      |                                                                      |
| 7    | Feb 25 – Feb 27 | 19: Carboxylic Acids  
20: Carboxylic Acid Derivatives                                            |                                                                      |
|      | Mar 4 – Mar 6  | Spring Break.                                                                 | No Class                                                              |
| 8    | Mar 11 – Mar 13 | 20: Carboxylic Acid Derivatives  
21: Amines and Their Derivatives                                             |                                                                      |
| 9    | Mar 18 – Mar 20 | 21: Amines and Their Derivatives  
22: Chemistry of Benzene Substituents                                      | Exam 2, Monday, 3/18, Ch 18, 19, 20, and 21 (partial)                  |
| 10   | Mar 25 – Mar 27 | 22: Chemistry of Benzene Substituents  
23: Ester Enolates and the Claisen Condensation                           | Last day to Withdraw via the web is Friday 3/29                        |
| 11   | April 1 – April 3 | 23: Ester Enolates and the Claisen Condensation  
25: Heterocycles                                                          |                                                                      |
| 12   | April 8 – April 10 | 25: Heterocycles                                                            |                                                                      |
| 13   | April 15 – April 17 | 10: Nuclear Magnetic Resonance (NMR)                                         | Exam 3, Monday, 4/15  
Ch 21 (partial), 22, 23, 25                                              |
| 14   | April 22 – April 24 | 11.8 – 11.10: IR Spectroscopy & Mass  
Spectrometry  
24, 26: Selected Topics from Carbohydrates and  
Amino Acids, Peptides, Proteins, and Nucleic Acids                         | **** Final Exam *******  
Monday, 4/29, 5:00pm – 7:00pm  
You must take the final at this time!                                    |
| Finals Week | April 29 – May 3 |                                                                                      |                                                                      |
The following problems listed below are suggested end-of-chapter problems (Independent Homework) to attempt. You should be able to do these problems and they might appear on an in-class examination. Many of the solutions to these problems are found in SAPLINGPLUS.

Chapter 15 – Benzene and Aromaticity
36(a-h), 38, 42(a-c), 47 – 49, 55, 56, 69-70

Chapter 16 – Electrophilic Attack on Derivatives of Benzene
30, 32 – 37, 40, 41, 43, 45, 57, 61, 64

Chapter 17 – Aldehydes and Ketones
27-28(a-e), 32-34, 36-37, 39, 48, 51, 55 and 56 (a-f,h,i), 57, 60, 68-69

Chapter 18 – Enols, Enolates, and the Aldol Condensation
32-33, 35, 37, 42-45, 47-52, 55(a-g)

Chapter 19 – Carboxylic Acids
27, 30, 33, 35-37, 40, 41, 45, 59-61

Chapter 20 – Carboxylic Acid Derivatives
30, 34, 36-37, 39-40, 42, 44, 45, 46(a-c), 49, 53, 68, 70, 71

Chapter 21 – Amines and their Derivatives
28, 35, 38(a-e), 39(a-b, d,g,h), 41, 43a, 44, 45, 63, 65, 66

Chapter 22 – Chemistry of Benzene Substituents
37-40, 42, 43(a,b), 46, 47, 53, 56, 57, 62, 68, 69(a-c), 76, 77

Chapter 23 – Ester Enolates and the Claisen Condensation
27, 28(a-g), 29, 30, 33, 37, 44, 53, 54

Chapter 25 – Heterocycles
31, 32(a,b), 35, 36a, 39(a-d), 40(a-c), 47, 53, 62, 63

Chapter 10 – Using NMR Spectroscopy to Deduce Structure

Chapter 11.8 – 11.10 – IR Spectroscopy and Mass Spectrometry
57, 59, 61-63, 78
**Course Learning Objectives**

**Chapter 15 - Learning Objectives**
* Name substituted benzenes
* Evaluate the concept of aromaticity by the criteria of structure, thermodynamics, molecular orbitals, and spectral properties
* Classify cyclic conjugated polyenes (annulenes) as aromatic, nonaromatic, and antiaromatic with the help of Hückel’s rule
* Explain the mechanism of electrophilic aromatic substitution and apply it to halogenation, nitration, sulfonation, and Friedel-Crafts alkylation and acylation

**Chapter 16 - Learning Objectives**
* Define electron-donating and electron-withdrawing substituents and describe their effect on the benzene ring
* Distinguish between inductively and resonance-induced electron donation and withdrawal
* Recognize the electronic origin of the ortho- and para-directing power of electron-donating substituents
* Recognize the electronic origin of the meta-directing power of electron-withdrawing substituents
* Recognize the electronic origin of the ortho- and para-directing power of the moderately electron-withdrawing halide substituents
* Evaluate steric effects as an additional contributor to the regioselectivity of electrophilic aromatic substitution
* Analyze the composite directing effects of multiple substituents on the position of electrophilic aromatic substitution
* Learn how to control the directing or blocking power of substituents through synthetic manipulations
* Apply the preceding principles to the synthesis of polycrystallized benzenes

**Chapter 17 - Learning Objectives**
* Draw the structures and formulate the names of aldehydes and ketones
* Describe the orbital makeup and polarity of the carbonyl double bond
* Review the methods for synthesizing aldehydes and ketones
* Classify the general mechanisms for addition reactions to aldehydes and ketones
* Recognize consequences of reversible addition reactions to aldehydes and ketones
* Apply the use of acetals as protecting groups in synthesis
* Illustrate methods for conversions of aldehydes and ketones into alkanes, alkenes, imines, and esters

**Chapter 18 - Learning Objectives**

* Recognize the α-hydrogens in aldehydes and ketones; understand the reasons for their acidity and the relative stability of their enolate conjugate bases
* Review keto-enol tautomerism and recognize its consequences
* Contrast α-halogenation of aldehydes and ketones under acidic and basic conditions
* Compare the feasibility of alkylation of aldehydes and ketones with that of enamines
* Describe the general mechanisms for aldol reactions of aldehydes and ketones
* Compare simple, crossed, and intramolecular aldol additions and condensations
* Illustrate the stability and reactivity of α,β-unsaturated aldehydes and ketones
* Compare and contrast reagents that prefer 1,2- vs. 1,4-addition to α,β-unsaturated aldehydes and ketones
* Utilize the Michael addition-Robinson annulation sequence for six-membered ring construction

**Chapter 19 - Learning Objectives**

* Draw the structures of and name carboxylic acids
* Describe the structural and physical properties of carboxylic acids
* Explain why and how carboxylic acids may act as both acids and bases
* Review older and introduce new methods for synthesizing carboxylic acids
* Discuss the general addition–elimination mechanisms for substitution at the carboxylic carbonyl carbon; recognize the role played by Le Châtelier’s Principle
* Illustrate the structures and preparative methods for carboxylic acid derivatives
* Recognize chemistry at the α-carbon of carboxylic acids and their derivatives

**Chapter 20 - Learning Objectives**

* Describe the structural features that differentiate the properties and reactivities of carboxylic acids and their derivatives
* Apply the general addition–elimination mechanism for substitution at the carbonyl carbon atoms of carboxylic acid derivatives

* Recognize the consequences of the different reactivities of carboxylic acid derivatives

* Discuss the methods and conditions for both hydrolyzing and interconverting carboxylic acid derivatives

* Illustrate reactions that transform carboxylic acid derivatives into other functionalized molecules

**Chapter 21 - Learning Objectives**

* Draw the structures and formulate the names of amines

* Describe the physical and spectral properties of amines

* Discuss the acid-base properties of amines

* Illustrate approaches to the preparation of alkanamines: alkylative methods, reductive amination of aldehydes and ketones, reduction of carboxylic amides, and the Hofmann rearrangement of carboxylic amides

* Examine three modes of reactivity of amines: elimination reactions of quaternary ammonium salts, α-aminomethylation of aldehydes and ketones, and N-nitrosation and its ramifications

**Chapter 22 - Learning Objectives**

* Illustrate the concept of benzylic resonance stabilization

* Describe benzylic reactivity in oxidations and reductions

* Discuss phenols: naming, preparation, and reactivity

* Introduce a new type of electrocyclic reaction of the benzene ring: the Claisen rearrangement

* Examine the redox chemistry of benzenediols

* Compare the modes of decomposition of arenediazonium salts to give substituted benzenes

**Chapter 23 - Learning Objectives**

* Describe the steps in the general mechanism of the Claisen condensation of esters

* Recognize the direction of the equilibria in each mechanistic step of the Claisen condensation and the role played by Le Châtelier’s principle in driving the reaction to completion

* Compare simple, crossed, and intramolecular Claisen condensations

* Apply retrosynthetic analysis to find suitable starting materials for a Claisen product

* Highlight the utility of β-dicarbonyl compounds as nucleophilic building blocks
* Explain the structural features of β-ketocarboxylic acids that permit facile decarboxylation
* Apply the Claisen condensation/alkylation/decarboxylation sequence to the synthesis of ketones and carboxylic acids
* Utilize β-dicarbonyl reagents in the Michael addition–Robinson annulation sequence

**Chapter 25 - Learning Objectives**

* Define and name heterocycles
* Categorize nonaromatic and aromatic heterocycles
* Discuss the syntheses and reactions of the heterocyclopentadienes pyrrole, furan, and thiophene
* Discuss the reactions of the azaaromatics pyridine, quinoline, and isoquinoline

**Chapter 10 - Learning Objectives**

* Define the various forms of spectroscopy, in particular nuclear magnetic resonance (NMR) spectroscopy
* Illustrate how the positioning of an NMR peak is diagnostic of the electronic environment of the nucleus giving rise to it
* Illustrate how the integration of NMR signals identifies the relative abundance of equivalent nuclei in a molecule
* Correlate the multiplicity of signals with the number of nonequivalent neighboring nuclei
* Employ proton and carbon NMR spectroscopy in the elucidation of the structure of organic molecules

**Chapter 11 - Learning Objectives**

* Correlate NMR spectroscopy and structure in alkenes
* Illustrate how infrared (IR) spectroscopy aids in structure determination
* Recognize the diagnostic absorptions in an IR spectrum
* Describe the principles of mass spectrometry and the information that it provides
* Recognize likely pathways of mass-spectrometric fragmentation
* Combine spectroscopy with molecular formula information for structure determination

**Chapter 24 – Learning Objectives** (selected topics from the following, may differ by instructor)

Chapter 24 - Learning Objectives
* Classify the types of carbohydrates

* Identify the stereocenters in open-chain monosaccharides and learn the meaning of the D,L nomenclature scheme

* Recognize the propensity for intramolecular hemiacetal formation in simple sugars

* Practice the representation of sugars in Haworth, Fischer, and chair-cyclohexane projections

* Recognize the anomeric carbon and distinguish α and β sugar anomers

* Apply standard transformations to the functional groups of sugars

* Distinguish reducing from non-reducing sugars

* Use the products of oxidative cleavage reactions to identify sugar structures

* Explain reactions at the anomeric carbon that give carbonyl derivatives

* Recognize the steps necessary for chain lengthening and chain shortening of sugars

* Describe the logic used by Fischer to elucidate sugar structures

* Expand the concept of glycoside formation to di- and polysaccharides

**Chapter 26 - Learning Objectives** (selected topics from the following, may differ by instructor)

* Describe the structure and acid-base properties of the 2- or α-amino acids

* Assess the relative merits of synthetic approaches to 2-amino acids

* Describe methods toward the construction of enantiomerically pure 2-amino acids

* Explain how the linking of multiple 2-amino acids through peptide bonds gives rise to polypeptides

* Assemble long polypeptide chains into higher order structures

* Determine the sequence of a polypeptide

* Apply protecting group strategies for the preparation of polypeptides

* Illustrate the structure of nucleic acids

* Explain how proteins are derived from the genetic code embedded in DNA

* Show how DNA is sequenced and synthesized