CHEM 2420 Organic Chemistry II

The University of Toledo
Department of Chemistry and Biochemistry
College of Natural Sciences and Mathematics
CRN 41940 (Section – 001)

Instructor: Prof. Peter R. Andreana, PhD
Email: peter.andreana@utoledo.edu
Office Hours: MF: 1-2 & 5-6
            W: 10-11
            Online Office Hours Only
Office Location: BO 2032B (Appt. Only)

Instructor Phone: 419-530-1930
Offered: Fall 2020
Course Website: Blackboard Learn
Class Location: Off Campus Location REMOTE – MWF
               2:30 -3:25 pm
Credit Hours: 3 Credits

CATALOG/COURSE DESCRIPTION
CHEM 2420 Organic Chemistry II
[3 credit hours (3, 0, 0)]
Study of structure and reactions of organic compounds. Three hours lecture per week.
Prerequisites: CHEM 2410 with a minimum grade of C-
Term Offered: Spring, Summer, Fall

COURSE OVERVIEW
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.

STUDENT LEARNING OUTCOMES - (See more after Course Schedule)
Consider each of these outcomes in terms of your understanding and abilities in Organic Chemistry as they are now at the start of this course. Consider these outcomes periodically throughout the semester.
As a result of your studies in CHEM 2420, you will demonstrate:
- an understanding of bonding of many types;
- an understanding of Nuclear Magnetic Resonance;
- an understanding of acid-base chemistry;
- an understanding of hydrocarbons, stereochemistry and resonance;
- confidence in your ability to analyze and solve synthetic problems;
- an ability to recognize and complete substitution and elimination reactions;
- an understanding of aromatic compounds and their reactions;
- an understanding of carbonyl chemistry (tetrahedral intermediates);
- effective time management and skills in note takings

TEACHING METHODOLOGY
The instructor will provide a learning environment such that students can meet the above outcomes. A variety of instruction techniques and assessment activities will be utilized to help you meet your potential in this class. Since this course will be taught entirely online, the instructor will utilize appropriate software.
in which ALL students will have available access. The instructor intends for you to finish this class with a new skill level in which to succeed in future chemistry courses and other college courses. Finally, the instructor respects your decision to study fields other than chemistry but encourages you to develop your interest in science.

**WORKWEEK**
All information can be found in the Course Schedule found below.

**PREREQUISITES AND COREQUISITES**
Prerequisites: CHEM 2410 with a minimum grade of C-. While it is not required, students are highly recommended to take CHEM 2460 or 2480 in the same semester. Students not satisfying the prerequisite will be removed from the course.

**TEXTS AND ANCILLARY MATERIALS**
- Access to a properly functioning computer with internet access in order to login to Blackboard (https://blackboard.utoledo.edu/).
- SAPLINGPLUS Learning online homework

**ANCILLARY MATERIALS**

**TECHNOLOGY REQUIREMENTS, SKILLS, AND PRIVACY POLICIES**
Please view the Technology Considerations for this course, including technical skills needed, general technology requirements, and technology privacy policies.

We will use Cisco WebEx™ for all our virtual online classes. Please see the UToledo Information Technology for web privacy and other information.

**TECHNOLOGY REQUIREMENTS FOR EXAMS**
LockDown Browser + Webcam Requirement

This course requires the use of LockDown Browser and a webcam for online exams. The webcam can be the type that's built into your computer or one that plugs in with a USB cable.

Watch this brief video to get a basic understanding of LockDown Browser and the webcam feature.

**Download Instructions**
Download and install LockDown Browser.

If you have any issues with the Webcam requirement please contact Dr. Andreana ASAP to arrange for alternate proctoring arrangements for the exams.
Students need to have access to a properly functioning computer throughout the semester. The Browser Check Page will enable you to perform a systems check on your browser and to ensure that your browser settings are compatible with Blackboard, the learning management system that hosts this course.

**Software:** Student computers need to be capable of running the latest versions of plug-ins, recent software and have the necessary tools to be kept free of viruses and spyware. The computer needs to run the following software, available in the UT Online Download Center.

- Word Processing Software
- Adobe Acrobat Reader
- Java Plugin Console
- Adobe Flash Player
- Adobe Shockwave Player
- Google Chrome Browser – Recommended

**Internet Service:** High-speed Internet access is recommended, as dial-up may be slow and limited in downloading information and for completing online tests. This course does contain streaming audio and video content.

**Use of Public Computers:** If using a public library or other public access computer, please check to ensure that you will have access for the length of time required to complete tasks and tests. A list and schedule for on-campus computer labs is available on the Open Lab for Students webpage.

**UT Virtual Labs:** Traditionally, on-campus labs have offered students the use of computer hardware and software they might not otherwise have access to. With UT’s Virtual Lab, students can now access virtual machines loaded with all of the software they need to be successful using nothing more than a broadband Internet connection and a web browser. The virtual lab is open 24/7 and 365 days a year at VLAB: The University of Toledo’s Virtual Labs.

**Learner Technical Support**

**ACCESSIBILITY OF COURSE TECHNOLOGIES**
Please view Accessibility of Course Technologies for information regarding the accessibility of Blackboard and other technologies used in this course. We will use Cisco WebEx™ for all our virtual online classes.

**ACADEMIC POLICIES**
Undergraduate Academic Policies
Please also see the Learner Support page for links and descriptions of the technical, academic, and student support services available to UT students.

**COURSE EXPECTATIONS**
All lecture videos will be available after the given lecture and for the entirety of the course.

- It is recommended that you read the textbook before entering the lecture.
- Complete the assigned Sapling online homework assignment before each posted deadline. There will be one assigned for each chapter. There are also some tutorials to complete.
- Complete the recommended end-of-chapter homework problems from the textbook. These are not collected or graded, this is recommended practice so that you can do your best on the exams.
• All online lectures, and online exams will be accessed through Blackboard. You should consult the site every class day.
• Anyone needing a P2P office meeting must contact me through email.

COMMUNICATION GUIDELINES
As your professor, I am here to help, and will do my best to respond to email within 24 to 48 hours. Students are expected to check their UT email account and Blackboard frequently for important course information. I 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:

<table>
<thead>
<tr>
<th>Component</th>
<th>Points</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sapling Homework Assignments</td>
<td>150 pts</td>
<td>21.3%</td>
</tr>
<tr>
<td>Practice Exam</td>
<td>5 pts</td>
<td>0.7%</td>
</tr>
<tr>
<td>Midterm Exams 3 @ 100 points each</td>
<td>300 pts</td>
<td>42.6%</td>
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<tr>
<td>Comprehensive Final Exam</td>
<td>200 pts</td>
<td>28.4%</td>
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<tr>
<td>Attendance</td>
<td>50 pts</td>
<td>7.1%</td>
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<tr>
<td><strong>Total:</strong></td>
<td><strong>705 pts</strong></td>
<td><strong>100%</strong></td>
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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 705 points.

Grade Scale: These are the minimum percentages needed to receive the indicated grade:
A 90% A– 87% B+ 84% B 80% B– 77% C+ 74% C 70% C– 67% D+ 64% D 60% D– 57%

Drop, Withdrawal and Incomplete Grades:
Course drop and withdrawal procedures have been set by the University of Toledo. Dropped courses do not appear on your transcript. Deadlines for dropping are found at the Office of the Registrar. 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 Office of the Registrar 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(s) for withdraw can be found on the Office of the Registrar website. If you drop or withdraw from 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; only for an acceptable reason.

Academic Dishonesty:
The academic dishonesty policy, as stated online will be STRICTLY ENFORCED. Any student found violating the UT academic dishonesty policy will be penalized accordingly.

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 Disabilities Act Compliance.

Academic Accommodations
The University of Toledo embraces the inclusion of students with disabilities. We are committed to ensuring equal opportunity and seamless access for full participation in all courses. For students who have an accommodations memo from Student Disability Services, I invite you to correspond with me as soon as possible so that we can communicate confidentially about implementing accommodations in this course. For students who have not established affiliation with Student Disability Services and are experiencing disability access barriers or are interested in a referral to healthcare resources for a potential disability or would like information regarding eligibility for academic accommodations, please contact the Student Disability Services Office by calling 419-530-4981 or sending an email to StudentDisability@utoledo.edu.

ACADEMIC AND SUPPORT SERVICES
Please view the Learner Support page for links and descriptions of the technical, academic, and student support services available to UT students.

SAFETY AND HEALTH SERVICES FOR UT STUDENTS
Please use the following link to view a comprehensive list Campus Health and Safety Services available to you as a student.
## COURSE SCHEDULE

<table>
<thead>
<tr>
<th>WEEK</th>
<th>DATES</th>
<th>Chapter: Topic</th>
<th>Notes</th>
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<tbody>
<tr>
<td>1</td>
<td>Aug 17 – Aug 21</td>
<td>10: Nuclear Magnetic Resonance (NMR)</td>
<td>First day of class – Aug 17</td>
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<td>2</td>
<td>Aug 24 – Aug 28</td>
<td>10: Nuclear Magnetic Resonance (NMR)</td>
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<td></td>
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<td>11.8 – 11.10: IR Spectroscopy &amp; Mass Spectrometry</td>
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<tr>
<td>3</td>
<td>Aug 31 – Sept 4</td>
<td>11.8 – 11.10: IR Spectroscopy &amp; Mass Spectrometry</td>
<td>Drop Deadline(s)</td>
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<tr>
<td>4</td>
<td>Sept 7 – Sept 11</td>
<td>15: Benzene and Aromaticity</td>
<td>Sept 7 – Labor Day (no classes)</td>
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<tr>
<td>5</td>
<td>Sept 14 – Sept 18</td>
<td>15: Benzene and Aromaticity</td>
<td>Online Exam – Spectroscopy – Sept 18</td>
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<td>16: Electrophilic Attack on Derivatives of Benzene</td>
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<tr>
<td>6</td>
<td>Sept 21 – Sept 25</td>
<td>16: Electrophilic Attack on Derivatives of Benzene</td>
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<td>17: Aldehydes and Ketones</td>
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<td>7</td>
<td>Sept 28 – Oct 2</td>
<td>17: Aldehydes and Ketones</td>
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<td>8</td>
<td>Oct 5 – Oct 9</td>
<td>18: Enols, Enolates, and the Aldol Condensation</td>
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<tr>
<td>9</td>
<td>Oct 12 – Oct 16</td>
<td>18: Enols, Enolates, and the Aldol Condensation</td>
<td>Online Exam – Carboxylic Acids and Benzene Substitution – Oct 16</td>
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<td>19: Carboxylic Acids</td>
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<tr>
<td>10</td>
<td>Oct 19 – Oct 23</td>
<td>19: Carboxylic Acids</td>
<td>Withdraw Deadline(s)</td>
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<tr>
<td>11</td>
<td>Oct 26 – Oct 30</td>
<td>20: Carboxylic Acid Derivatives</td>
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<td>12</td>
<td>Nov 2 – Nov 6</td>
<td>21: Amines and Their Derivatives</td>
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<td>13</td>
<td>Nov 9 – Nov 13</td>
<td>22: Chemistry of Benzene Substituents</td>
<td>Nov 11 – Veterans Day (no classes)</td>
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<td>Online Exam – Aldol, Carboxylic Acids and Amines – Nov 13</td>
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<td>14</td>
<td>Nov 16 – Nov 20</td>
<td>22: Chemistry of Benzene Substituents</td>
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<td>23: Ester Enolates and the Claisen Condensation</td>
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<td>15</td>
<td>Nov 23 – Nov 27</td>
<td>23: Ester Enolates and the Claisen Condensation</td>
<td>Nov 25 – No classes</td>
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<td>25: Heterocycles?</td>
<td>Nov 27 – Thanksgiving Break (no classes)</td>
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<td>Finals Week</td>
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<td>****** Online Final Exam******</td>
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<td>Monday, Nov 30, 2:45-4:45 p.m.</td>
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<td>You must take the final at this time!</td>
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*Subject to change based on pace of class.*
# Important Class Sampling Assignment Dates

<table>
<thead>
<tr>
<th>Dates</th>
<th>Action Item</th>
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<tbody>
<tr>
<td>Aug 17</td>
<td>Out: Homework Assignment #1 – Chapter 10</td>
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<tr>
<td>Aug 24</td>
<td>Out: Homework Assignment #2 – Chapter 11</td>
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<tr>
<td>Aug 28</td>
<td>In: Sampling &amp; Homework Assignment #1 – Chapter 10</td>
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<tr>
<td>Sept 9</td>
<td>Out: Homework Assignment #3 – Chapter 15</td>
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<tr>
<td>Sept 9</td>
<td>In: Homework Assignment #2 – Chapter 11</td>
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<tr>
<td>Sept 18</td>
<td>Out: Homework Assignment #4 – Chapter 16</td>
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<tr>
<td>Sept 18</td>
<td>In: Homework Assignment #3 – Chapter 15</td>
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<tr>
<td>Sept 25</td>
<td>Out: Homework Assignment #5 – Chapter 17</td>
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<tr>
<td>Sept 30</td>
<td>In: Homework Assignment #4 – Chapter 16</td>
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<tr>
<td>Oct 5</td>
<td>Out: Homework Assignment #6 – Chapter 18</td>
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<tr>
<td>Oct 9</td>
<td>In: Homework Assignment #5 – Chapter 17</td>
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<td>Oct 19</td>
<td>Out: Homework Assignment #7 – Chapter 19</td>
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<tr>
<td>Oct 19</td>
<td>In: Homework Assignment #6 – Chapter 18</td>
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<tr>
<td>Oct 23</td>
<td>Out: Homework Assignment #8 – Chapter 20</td>
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<tr>
<td>Oct 30</td>
<td>In: Homework Assignment #7 – Chapter 19</td>
</tr>
<tr>
<td>Nov 2</td>
<td>Out: Homework Assignment #9 – Chapter 21</td>
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<tr>
<td>Nov 4</td>
<td>In: Homework Assignment #8 – Chapter 20</td>
</tr>
<tr>
<td>Nov 9</td>
<td>Out: Homework Assignment #10 – Chapter 22</td>
</tr>
<tr>
<td>Nov 13</td>
<td>In: Homework Assignment #9 – Chapter 21</td>
</tr>
<tr>
<td>Nov 16</td>
<td>Out: Homework Assignment #11 – Chapter 23</td>
</tr>
<tr>
<td>Nov 25</td>
<td>In: Homework Assignment #10 – Chapter 22</td>
</tr>
<tr>
<td>Nov 27</td>
<td>In: Homework Assignment #11 – Chapter 23</td>
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</tbody>
</table>

*Subject to change based on pace of class.*
STUDENT LEARNING OUTCOMES – cont’d

Please see Learning Objectives here:

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 15 - Learning Objectives
Name substituted benzenes
Evaluate the concept of aromaticity by the criteria of structure, thermodynamics, molecular orbitals, and spectral properties
Expand the concept of aromaticity to polycyclic benzenoid hydrocarbons
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 polysubstituted benzenes
Extend these principles to the electrophilic substitution of polycyclic aromatic hydrocarbons
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
Recognize the spectroscopic features that indicate the presence of a carbonyl group
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
Recognize the spectroscopic features that characterize 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
Demonstrate the concept of acyl anion equivalents in the form of cyclic thioacetal anions as reagents and thiazolium salts as catalysts

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 syntheses and reactions of the azaaromatics: pyridine, quinoline, and isoquinoline
Describe heterocyclic compounds in nature: alkaloids

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 exam. Many of the solutions to these problems are found in SAPLINGPLUS. A great way to study would be to have a WebEx or Zoom study session with your class colleagues.

Unit I: Chapters 10-11
Chapter 10 – Using Nuclear Magnetic Resonance Spectroscopy to Deduce Structure

Chapter 11 – Alkenes: Infrared Spectroscopy and Mass Spectrometry
Chapter 15 – Benzene and Aromaticity

Chapter 16 – Electrophilic Attack on Derivatives of Benzene
30, 32-37, 39-46, 48-49, 51-52, 54, 56-60, 62, 64

Chapter 17 – Aldehydes and Ketones

Chapter 18 – Enols, Enolates and the Aldol Condensation

Chapter 19 – Carboxylic Acids

Chapter 20 – Carboxylic Acid Derivatives
30-31, 34-43, 45-46, 52, 54-55, 57, 60, 62-63, 66-71

Chapter 21 – Amines and Their Derivatives

Chapter 22 – Chemistry of Benzene and Substituents

Chapter 23 – Ester Enolates and the Claisen Condensation
28-30, 32-34, 37, 40-42, 46-56