



## COURSE OUTLINE

<b>Course Number</b> <b>CHE202</b>	<b>Course Title</b> <b>Organic Chemistry II</b>	<b>Credits</b> <b>5</b>
<b>Hours:</b> <b>Lecture/Lab/Other</b> <b>3/4</b>	<b>Co- or Pre-requisite</b> <b>CHE 201</b>	<b>Implementation</b> <b>Semester &amp; Year</b> <b>Spring 2022</b>

### Catalog description:

A continuation of CHE 201. Theoretical principles and underlying reaction mechanisms are presented along with descriptive aspects of the preparation, reactions and major uses for key classes of organic compounds. Topics covered include: aromatic hydro-carbons and their electrophilic substitution products, aldehydes and ketones, carboxylic acids and their derivatives, amines, phenols, and carbohydrates. Laboratory work includes methods of synthesis, purification and identification of organic compounds.

### General Education Category:

#### Goal 3: Science

### Course coordinator:

**Helen V. Tanzini, Professor of Chemistry**  
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### Required texts & Other materials:

#### ORGANIC CHEMISTRY

Authors: T.W. Graham Solomons and Craig B. Fryhle

Publishers: John Wiley & Sons. Inc.

Edition: Twelfth, 2016

ISBN: 978-1-118-87576-6

#### CHE202 Supplementary Notes

Authors: H.V Tanzini

Publishers: MCCC

Edition: Second edition, 2022

#### EXPERIMENTAL ORGANIC CHEMISTRY, a Miniscale and Microscale Approach

Authors: John C. Gilbert, and Stephen F. Martin

Publisher: Thomson Brooks/Cole Publishing

Edition: Sixth, 2016

ISBN: 978-1-305-08046-1

#### STUDENT LAB NOTEBOOK With Spiral Binding

(100 carbon duplicate sets)

ISBN 1930882742

Publisher: Hayden-McNeil Specialty Products

## Course Student Learning Outcomes (SLO):

### ***Upon successful completion of this course the student will be able to:***

1. Explain and interpret key concepts of organic chemistry including aromaticity, enolate, spectroscopy, organic multi-step synthesis and reaction mechanisms functional groups and acid-base behavior [ILG Goals 3 & 11; PLOs# 1-5]
2. Design, evaluate and conduct multi-step, complex synthetic methods by use of retro-synthetic analysis then characterize the products. [ILG Goals 3 & 11; PLOs# 1-5]
3. Create and evaluate organic reaction mechanisms using curved arrows including stereochemistry and adaptation of this skill to new situations [ILG Goals 3 & 11; PLOs# 1-5]
4. Use scientific instruments and interpret data from instrumental analysis of synthesized compounds (IR, NMR, mass spec) and unknowns (IR, NMR) [ILG Goals 3,4 & 11 PLOs# 1-5]
5. Demonstrate safety in the organic laboratory setting and practice environmentally sound waste disposal methods [ILG Goals 3&11; PLOs# 1-5]
6. Communicate scientific information in the form a laboratory reports and conduct literature searches then evaluate and analyze their findings [ILG Goals 1, 3 & 10,11; PLOs# 1-5]

## Course-specific Institutional Learning Goals (ILG):

**Institutional Learning Goal 1. Written and Oral Communication in English.** Students will communicate effectively in both speech and writing.

**Institutional Learning Goal 3. Science.** Students will use the scientific method of inquiry, through the acquisition of scientific knowledge.

**Institutional Learning Goal 4. Technology.** Students will use computer systems or other appropriate forms of technology to achieve educational and personal goals.

**Institutional Learning Goal 10. Information Literacy:** Students will recognize when information is needed and have the knowledge and skills to locate, evaluate, and effectively use information for college level work.

**Institutional Learning Goal 11. Critical Thinking:** Students will use critical thinking skills understand, analyze, or apply information or solve problems.

## Program Learning Outcomes for Chemistry A.S. Program (PLO):

1. Demonstrate an understanding of the fundamental principles, concepts and terminology of chemistry
2. Develop a working knowledge of chemical principles and methods including problem solving, analytical reasoning and laboratory skills.
3. Utilize critical thinking, qualitative and quantitative reasoning skills to organize, evaluate and interpret data expressing the results in a clearly written laboratory report or in an oral presentation.
4. Conduct literature searches and communicate findings orally and in writing
5. Plan, execute, and interpret an experiment according to the Scientific Method using proper scientific and laboratory safety procedures and maintaining an accurate and complete laboratory notebook

## Units of study in detail – Unit Student Learning Outcomes:

### UNIT 13      Alcohols [Supports SLO #1,2,3]

*The student will be able to...*

1. Given the structure of an alcohol, write an appropriate IUPAC name or given a name draw the corresponding structure.
2. Classify any given alcohol as primary (1°), secondary (2°) or tertiary (3°).
3. Explain why alcohols have boiling points which are much higher than those of hydrocarbons of corresponding molecular weight.
4. Write equations for at least two processes by which alcohols are made in large scale commercial quantities

5. Show, by suitable equations, how primary, secondary, and tertiary alcohols can be made via the Grignard reagent and alkyl lithium reagents.
6. Show, by suitable equations, how alcohols can be made from alkenes using the hydroboration-oxidation reaction.
7. Write a mechanism for the hydroboration-oxidation reaction which accounts for primary alcohol formation (Syn addition).
8. Show, by suitable equations, how alcohols can be made from alkenes by the oxymercuration-demercuration reaction.
9. Show, by suitable equations, how alcohols can be converted into alkenes and alkyl halides (include mechanisms).
10. Show, by suitable equations, how alcohols can be oxidized into aldehydes, ketones, and carboxylic acids.
11. Describe what the Lucas test is; what its limitations are; and how it can be used to differentiate primary, secondary, and tertiary alcohols.
12. Write an equation for the conversion of alcohols to mesylates and tosylates followed by SN2 reactions. **3**

#### **UNIT 14      Ethers and Epoxides [Supports SLO #1,2,3]**

*The student will be able to...*

1. Given the structure of an ether and write an appropriate name, or given a name, draw the corresponding structure
2. Write equations for two methods of preparing ethers.
3. Given a particular ether, choose the appropriate reagents and create a synthesis of the ether by the Williamson synthesis.
4. Show, by suitable equations, how ethers may be cleaved by selected strong acids.
5. Name and draw the structures of at least two cyclic ethers.
6. Draw the structure of an epoxide
7. Given the structure of an epoxide, write an appropriate name; or given a name, draw the corresponding structure.
8. Write equations illustrating at least two general methods for epoxide preparation.
9. Write equations for the reaction of epoxides with at least three classes of active hydrogen compounds.
10. Describe how alcohol protecting groups are used (*tert*-butyl and trimethylsilyl groups).
11. Write mechanisms for acid catalyzed and base catalyzed opening of an epoxide (symmetrical and unsymmetrical).

#### **UNIT 15      Alcohols from Carbonyl Compounds [Supports SLO #1,2,3]**

*The student will be able to...*

1. Write a mechanism illustrating nucleophilic addition to a carbonyl compound.
2. Write equations for the formation of an alcohol from the reduction of a carboxylic acid, ester, aldehyde and ketone.
3. Write equations for the oxidation of alcohols to form various carbonyl compounds.
4. Write an equation for the reaction of a primary alcohol with pyridinium chlorochromate.
5. Write equations and mechanisms for organolithium and organomagnesium (Grignard) reactions, and plan a synthesis using these reagents.
6. Write an equation for the reaction of an epoxide with organometallic compounds such as Grignard reagents.

#### **UNIT 16      Spectroscopy and Structure [Supports SLO #1,2,3]**

*The student will be able to...*

1. Describe the kind of changes which may take place in a molecule as a result of absorption of energy in the ultraviolet region of the electromagnetic spectrum.
2. Describe the kinds of changes which may take place in a molecule as a result of absorption of energy in the infrared region of the electromagnetic spectrum.
3. Define and differentiate among the terms: WAVELENGTH, WAVE NUMBERS, FREQUENCY, AND RECIPROCAL CENTIMETERS as used in infrared spectroscopy.

4. Given the typical infrared region of interest to the organic chemist lies between 2 and 15 microns (or between 650 and 5000  $\text{cm}^{-1}$ ) indicate which part of this is considered the "characteristic group absorption region" and which the "fingerprint region."
5. Define what is meant by the "characteristic group absorption region" of the infrared spectrum
6. Define what is meant by the "fingerprint region" of the infrared spectrum.
7. Given the infrared spectrum of a pure simple organic compound, the molecular formula of the compound, and a table of characteristic infrared absorption frequencies, draw the likely structure of the compound
8. Define the term chemical shift as it applies to nuclear magnetic resonance (NMR) spectroscopy.
9. Explain the role of shielding and deshielding in NMR spectroscopy with respect to compound identification
10. Generate a representative NMR spectrum labeling it with appropriate delta scale of an organic compound.
11. a. Name and draw the structure of the most commonly used compound for establishing the reference point from which chemical shifts are measured in NMR spectroscopy  
b. State why this particular compound is chosen for such use.
12. Explain the "cause" of signal splitting in the NMR spectrum.
13. Given a proton and its environment, predict whether that proton will show a single peak, a doublet, a triplet, a quartet, etc., in the NMR spectrum.
14. Given the molecular formula and integrated NMR spectrum of a pure compound, predict the probable structure of the compound.
15. State the kind of information about molecules which can be obtained from carbon-13 NMR spectroscopy.
16. Define the term molecular ion (m/e value) as used in mass spectroscopy,
17. State the kind of structural information about an organic compound that is obtainable by mass spectroscopy.
18. Given a mass spectrum, identify the base peak, the molecular ion or parent peak, and the M + 1 and M + 2 peaks if present.

### **UNIT 17      Resonance and Dienes [Supports SLO #1,2,3]**

*The student will be able to...*

1. Write a mechanism for substitution reactions of alkenes leading to allylic compounds.
2. Describe why allylic substitution reactions can be made to take place as opposed to vinylic substitution reactions or alkene addition reactions.
3. Explain the principles of the concept of resonance connected to compound reactivity
4. Define the terms resonance energy or delocalization energy
5. Describe and illustrate what is meant by the resonance structures of the allylic radical.
6. Analyze the concept of hyperconjugation of alkyl radicals.
7. Given a structure, name any given diene using the IUPAC system of nomenclature, or given an IUPAC name draw the corresponding structure.
8. Using appropriate structural formulas, illustrate what is meant by CONJUGATED, CUMULATED and ISOLATED double bonds in a diene structure.
9. Write a mechanism for the electrophilic addition reaction of dienes differentiating between 1,2-, and 1,4-addition.
10. Differentiate between rate (kinetic) controlled yields and equilibrium (thermodynamic) controlled yields in organic reactions.
11. Predict then evaluate the outcome of kinetic and thermodynamically controlled reactions
11. Write a mechanism for the free radical addition to conjugated dienes differentiating between 1,2- and 1,4-addition.]
12. Design multi-step synthesis of compounds using Diels Alder reaction.

### **UNIT 18      Benzene and Aromatic Compounds [Supports SLO #1,2,3]**

*The student will be able to...*

1. Give the original meanings for the terms aliphatic and aromatic compounds.
2. Define aromatic compounds in terms of current practice.
3. Illustrate the Kekule structure of benzene.
4. Compare the principles of the concept of resonance with reactivity of aromatic compounds.
5. Define the terms resonance energy or delocalization energy.
6. Describe what is meant by the resonance structure of benzene and its stability.
7. Cite at least four pieces of experimental evidence in support of the resonance structure of benzene.

8. Draw a molecular orbital representation of benzene
9. Using the Huckel  $4n + 2$  rule, determine whether or not a given structure should have aromatic character.
10. Given a substituted benzene structure, assign an appropriate name or given a name draw the correct structure.
11. Use NMR and IR spectroscopy for structure assignment of aromatic compounds.

## **UNIT 19      Electrophilic Aromatic Substitution [Supports SLO #1,2,3]**

*The student will be able to...*

1. Write equations to show the halogenation, nitration, sulfonation, and Friedel-Crafts alkylation of given aromatic compounds indicating the preferred isomers to be expected.
2. List atoms or groups which when present on an aromatic ring can activate the ring toward further substitution reactions as compared to the reactivity of benzene itself.
3. List atoms or groups which when present on an aromatic ring can deactivate the ring toward further substitution reactions as compared to the reactivity of benzene itself.
4. Write a series of structures and equations to illustrate the mechanism by which electron withdrawing groups deactivate aromatic rings toward further substitution.
5. Define and illustrate the term inductive effect.
6. List atoms or groups which, when present on an aromatic ring will direct subsequent incoming substituents into ortho- and para- positions.
7. List atoms or groups which, when present on an aromatic ring, will direct subsequent incoming substituents into the meta positions.
8. Explain, in mechanistic terms and using suitable illustrative structures and equations, the basis for ortho-, meta-, and para-directive effects.
9. Write a mechanism for the halogenation, nitration, sulfonation, and the Friedel-Crafts alkylation of aromatic compounds.
10. Define the term and give an example of an arene.
11. Given the structure of a typical arene write an appropriate name or given a name draw the correct structure. [
12. Name two major sources of arenes and indicate the typical kinds of arenes obtainable from each.
13. Write balanced equations for at least two general methods of arene synthesis.
14. Write a balanced equation for a Friedel-Crafts alkylation reaction.
15. Write out one of the two generally accepted mechanisms for a Friedel-Crafts alkylation reaction and indicate how it differs from the other generally accepted mechanism.
16. Write balanced equations for at least two reactions of arenes: one of which involves reaction of the ring; and the other of which involves reaction of the alkyl group
17. Define the term benzylic hydrogen.
18. Identify the benzylic hydrogens of a given arene.
19. State or illustrate what factors or conditions favor side-chain halogenation of an arene.
20. Write a mechanism for the free radical side-chain halogenation of an arene.
21. State the factors responsible for the stability of a benzylic free radical.
22. Write equations to show the carbocation mechanism for the addition reactions of alkenylbenzenes.
23. List in decreasing order of stability the free radicals and or carbocation derived from allyl groups, benzyl groups, methane, primary, secondary or tertiary alkyl groups, and vinyl groups.

## **UNIT 20      Aldehydes and Ketones I [Supports SLO #1,2,3]**

*The student will be able to...*

1. By means of a generalized structure, distinguish between aldehydes and ketones
2. Draw a molecular orbital representation of the carbonyl group of an aldehyde or ketone and indicate the type of hybridization undergone by the carbonyl carbon atom.
3. Given the structure of an aldehyde or ketone, write the corresponding IUPAC name; or given a name, draw the corresponding structure.
4. Write balanced equations for at least three methods for preparing aldehydes and ketones

5. Write balanced equations for the reaction of aldehydes or ketones with hydrogen, water, alcohols, and Grignard reagents. Given a specific aldehyde or ketone, be able to write an appropriate equation involving reaction with the reagents noted above; draw the structure of the resulting products; and, name the product or products.
6. Write balanced equations for the reaction of aldehydes or ketones with hydroxylamine, semicarbazide, phenylhydrazine, hydrazine, 2,4-dinitrophenylhydrazine and hydrogen cyanide and be able to name the products formed.
7. Write a balanced equation for the Wittig reaction and create multi-step syntheses using Wittig reaction.
8. Write equations illustrating the Reformatsky reaction and Baeyer-Villiger Oxidation reaction and create multi-step syntheses.
9. Know the chemical tests for aldehydes and ketones.
10. Generate a structural formula for a compound by evaluating the IR, NMR and molecular formula.

## **UNIT 21      Aldehydes and Ketones II [Supports SLO #1,2,3]**

*The student will be able to...*

1. Explain why hydrogens that are alpha to a carbonyl group, nitro group, or nitrile are acidic.
2. Write equations illustrating keto and enol tautomers formed via an enolate ion
3. Explain for racemization when a ketone or aldehyde is left in an acid or base.
4. Write equations for acid or base catalyzed halogenation of a ketone, the haloform reaction, and the Iodoform test.
5. Create reaction mechanisms for acid or base catalyzed Aldol reaction and crossed Aldol reaction.
6. Synthesize new compounds containing rings via Aldol condensations.
7. Write equations and mechanisms for simple addition and conjugate addition of nucleophiles to  $\alpha,\beta$  unsaturated aldehydes and ketones.

## **UNIT 22      Carboxylic Acids [Supports SLO #1,2,3]**

*The student will be able to...*

1. Given a structure of carboxylic acid, write an appropriate name, including IUPAC names of aliphatic carboxylic acids; or given a name, draw the corresponding structure.
2. Given the structure of a dicarboxylic acid, write an appropriate name; or given a name, draw the corresponding structure
3. Explain why carboxylic acids have boiling points higher than alcohols and significantly higher than hydrocarbons of corresponding molecular weight
4. Define the term acidity constant,  $K_a$ , for a carboxylic acid.
5. Explain the acidity of carboxylic acids in terms of carboxylate anion stability.
6. Analyze role inductive effects play on the acidity of a given carboxylic acid.
7. Explain why some substituents increase the acidity of a carboxylic acid and other substituents decrease the acidity.
8. Given a list of carboxylic acids, predict, on the basis of structural features or substituents present, an order of probable increasing or decreasing acid strength as requested.
9. Given a list of carboxylic acids, and their  $K_a$  values, classify the acids in order of increasing or decreasing acid strength as requested.
10. Given the structure of nitrile, write an appropriate name; or given a name draw the corresponding structure.
11. Write equations for three methods of preparing carboxylic acids, including dicarboxylic acids.
12. Write equations for four reactions of carboxylic acids
13. Name a reagent which can be used for the direct reduction of a carboxylic acid to an alcohol and write an equation illustrating its use.

## **UNIT 23      Carboxylic Acid Derivatives [Supports SLO #1,2,3]**

*The student will be able to...*

1. Given the structure of a carboxylic acid amide, anhydride, ester, or halide, write an appropriate name; or given a name, draw the corresponding structure
2. Write an equation for at least one method of preparation of an acid amide, anhydride, and halide.
3. Write an equation for at least one reaction which can be undergone by an acid amide, anhydride, or halide.
4. Write an equation for the Friedel-Crafts acylation of aromatic ring-containing compounds

5. Create a mechanism which shows how the carbonyl group of a carboxylic acid or carboxylic acid derivative becomes involved in nucleophilic substitution reactions.
6. Evaluate equations for three methods of preparing esters for use in synthesis
7. Evaluate equations for four kinds of reactions esters can undergo.
8. Create a mechanism for the alkaline hydrolysis of an ester.
9. Create a mechanism for the acidic hydrolysis of an ester.
10. Describe in detail, with suitable equations, at least one method which can be used to establish the fate of the non-carbonyl oxygen during ester hydrolysis
11. Write an equation for the preparation of tertiary alcohols using the reaction of an ester with a Grignard reagent.

## **UNIT 24      Chemistry of Enolate Ions [Supports SLO #1,2,3]**

*The student will be able to...*

1. Explain why  $\beta$ -keto esters are stronger acids than ethanol.
2. Write equations and create mechanisms for the following reactions: Claisen condensation, crossed Claisen condensation, acetoacetic ester synthesis, malonic ester synthesis, and the Knoevenagel condensation.
3. Illustrate what is meant by "active hydrogen compounds."
4. Write equations for direct alkylation of esters and nitriles.
5. Describe what is meant by "Michael addition."
6. Use Michael Addition reactions in multi-step synthesis or organic compounds.

## **UNIT 25      Amines [Supports SLO #1,2,3]**

*The student will be able to...*

1. Define primary ( $1^\circ$ ), secondary ( $2^\circ$ ), and tertiary ( $3^\circ$ ) amine, and be able to correctly classify any give amine as  $1^\circ$ ,  $2^\circ$ , or  $3^\circ$
2. Given the structure of an amine, write an appropriate name, or given a name, draw the corresponding structure.
3. Illustrate, by suitable equations, how the basicity constant,  $K_b$ , of an amine is derived.
4. Describe and illustrate, with appropriate structures and equations, factors which tend to increase the basicity of an amine and factors which tend to decrease the basicity of the amine.
5. Given a list of amines and their  $K_b$  values, evaluate the amines in order of decreasing or increasing basic strengths as requested
6. Given a series of closely related amines, predict, on the basis of structural features or substituents an order of probable increasing or decreasing basic strength as requested.
7. Write equations, including all key reagents involved, for at least three methods of preparing amines. Critique the methods for feasibility and application to multi-step synthesis
8. Draw the structure of a quaternary ammonium salt; name it and by means of suitable equations indicate how it can be made.
9. Show, by means of suitable equations, the products, if any, of the reaction of  $1^\circ$ ,  $2^\circ$ , and  $3^\circ$  amines with acid halides.
10. Write an equation for the preparation of an amine from an amide.
11. Describe and differentiate between the results of the reaction of nitrous acid with  $1^\circ$ ,  $2^\circ$ , and  $3^\circ$  aliphatic and aromatic amines
12. Draw a general structure for a diazonium salt.]
13. Distinguish between the stability of diazonium salts derived from  $1^\circ$  aliphatic or aromatic amines and indicate what diagnostic or synthetic value such diazonium salts might have.
14. Write a general equation for the preparation of a diazonium salt.
15. Write an equation showing the replacement of a diazonium group by -OH, -OR, -halide, -cyanide, -H, and -NO<sub>2</sub> noting any particular conditions required to plan the indicated reaction. (Sandmeyer reaction)
16. Write an equation for the preparation of an azo dye by a diazonium salt coupling reaction.
17. Write an equation for the preparation of a sulfonamide from the reaction of an amine with sulfonyl chlorides (Hinsberg test).
18. Use chemical tests, IR, <sup>1</sup>H NMR, <sup>13</sup>C NMR for structure assignment of amines. Justify the structure by relating it to all of the data.
19. Write equations for the Hofmann elimination reaction and the Cope elimination reaction.
20. Illustrate the amine reactions that we have studied using heterocyclic amines.

## **UNIT 27      Carbohydrates [Supports SLO #1,2,3]**

*The student will be able to...*

1. Define the term carbohydrate and give an example.
2. Define the terms monosaccharide, disaccharide, and polysaccharide and name at least one specific example of each.
3. Classify a given sugar as an aldotriose, aldotetrose, aldo-pentose, aldohexose, ketotriose, ketotetrose, ketopentose, or ketohexose.
4. Draw the Fisher projection formula and the Haworth formula for glucose.
5. Define and illustrate the terms anomer, diastereomer, enantiomer, meso form, and racemic mixture.
6. Given the Fisher projection formula of a sugar, classify the configuration of the sugar as D or L
7. Describe what is meant by MUTAROTATION
8. Describe, with the aid of suitable equations, the chemical basis of the Benedict's or Fehling's test for reducing sugars.
9. Indicate what structural feature must be present or capable of being formed in aqueous solution for a sugar to act as a reducing sugar.
10. Draw Fisher and Haworth formulas for the alpha and beta anomeric forms of glucose.
11. Define the term glycoside, draw the structure of an example, and name the structure you have drawn
12. Define what is meant by glycosidic linkage and illustrate it by drawing the structure of a disaccharide.
13. Given a list of structures and names, be able to match the name to the structure for the monosaccharides fructose, galactose, glucose, 2-deoxyribose, and ribose; the disaccharides cellobiose, lactose, maltose, and sucrose; and polysaccharide segments of amylopectin, amylose, cellulose and glycogen

## **LABORATORY [Supports SLO #2,4,5,6]**

*The student will be able to:*

- Prepare and organize laboratory notebook prior to coming to class.
- Maintain a laboratory notebook that is accurate and up to date
- Demonstrate safety in the laboratory
- Prepare organic compounds using safe and proper lab techniques
- Complete syntheses using separation, purification and assessment methods
- Use IR spectrophotometer, NMR spectroscopy, chromatography and Meltemp for data acquisition then analyze the data compound identification and purity

### **Evaluation of student learning:**

Grading: Letter grades will be assigned based on the total number of points earned in the course as compared to the total number of possible points. The percentage breakdown for letter grades is shown on the next page.

Three Hour examinations, highest 10 of 11 quizzes, and laboratory work will contribute to the total points as shown in the point composition column.

### **Letter Grades**

<u>% of maximum</u> <u>points</u>	<u>Grade</u>	<u>Point Composition</u>	
93 - 100%	A	Hour Examinations	37.5%
90 - 92%	A-	Quizzes	12.5%
87 - 89%	B+	Final Examination	20%
83 - 86%	B	Laboratory Work*	30%
80 - 82%	B-		
77 - 79%	C+		
70 - 76%	C		
60 - 69%	D		
0 - 59%	F		

\*Acceptable laboratory participation and performance is required to pass the course.