



COURSE OUTLINE

Course Number CHE201	Course Title Organic Chemistry I	Credits 5
Hours: Lecture/Lab/Other 3/4	Co- or Pre-requisite CHE 102	Implementation Semester & Year Spring 2022

Catalog description:

Theoretical principles of reaction mechanisms and the synthesis of important classes of organic compounds. Topics include stereoisomerism; alcohols; ethers; nucleophilic substitution; elimination reactions; and instrumental methods. Lab work introduces the synthesis, purification, separation and identification of organic compounds.

General Education Category:

Goal 3: Science

Course coordinator:

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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

CHE201 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 nomenclature, stereochemistry, organic synthesis and reaction mechanisms based on functional groups and acid-base behavior [ILG Goals 2,3 &11; PLOs# 1-5]
2. Design and evaluate multi-step synthetic methods by use of retro-synthetic analysis. [ILG Goals 1, 2, 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. Demonstrate safety in the organic laboratory setting and practice environmentally sound waste disposal methods [ILG Goals 3 &11; PLOs# 1-5]
5. Communicate scientific information in the form a laboratory reports and conduct literature searches then evaluate and analyze their findings [ILG Goals 1,2,3 &11; PLOs# 1-5]
6. Perform and master the basic techniques for: (i) the separation and purification of organic compounds (recrystallization, distillation, column chromatography), (ii) the analysis of organic compounds (TLC, gas chromatography) and (iii) the characterization of organic compounds (melting and boiling points, IR spectroscopy [ILG Goals 2, 3 &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 2. Mathematics. Students will use appropriate mathematical and statistical concepts and operations to interpret data and to solve problems.

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

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 1 Introduction to Organic Chemistry [Supports SLO #1,2,3]

The student will be able to...

1. Define organic chemistry]
2. Name the element found in all organic compounds.
3. Name at least four other elements frequently found as part of an organic compound.
4. Given the atomic weight and number of one of the first 20 elements in the periodic table, write the electronic configuration of that element, and/or of the most common ion obtainable from the element.

- Define what is meant by an ionic bond.
- Show, by suitable illustrations using electron dot (Lewis) or Bohr representations, how two elements might form an ionic (electrovalent) bond between them.
- Define what is meant by a covalent bond.
- Show by suitable illustration how two elements might form a covalent bond between them.
- Illustrate by a suitable labeled drawing of a simple molecule what is meant by the term dipole.
- Given access to a periodic table, indicate which of any two given elements is the more electronegative one.
- Given the Pauling electronegativities of elements which are joined by a covalent bond, indicate the direction of the dipole in the bond and indicate whether the bond is likely to be weakly, moderately or strongly polarized.
- Using electron dot (Lewis) formulas, show the structure of a molecule containing coordinate-covalent bonds and by means of a small arrow or polarity (+,-) signs, indicate which bond or bonds are coordinate-covalent.
- List at least three differences in the typical physical properties of IONIC and covalent compounds.
- Indicate, using appropriate illustrations, the role of solvation on the solubility of compounds.

Unit 2 BONDS INVOLVING CARBON [Supports SLO #1,2,3]

The student will be able to...

- Draw a representation of an s and p atomic orbital.
- Write the electronic configuration of a carbon atom.
- State and/or illustrate Pauli's exclusion principle.
- State and/or illustrate Hund's rule]
- Define what is meant by a sigma bond.
- Illustrate sigma bond formation between two atoms.
- By illustrative example describe and show why a tetrahedral structure rather than a planer structure is believed to result when four other atoms are bonded to a single carbon atom.
- Define, illustrate and differentiate between the terms empirical, molecular, and structural formula.
- Define the term stereoisomerism.
- Define the term isomer.
- Describe and illustrate how the carbon atom as it appears in molecules differs in its apparent electronic configuration from what might be expected from the "expected" "ground" state electronic configuration of the carbon atom.
- Describe what is meant by a sp³ hybridized carbon atom.
- Illustrate an sp³ hybridized carbon atom.
- Illustrate sigma bond formation in methane.
- Illustrate an sp² hybridized carbon atom.
- Illustrate an sp hybridized carbon atom.
- Indicate the kind of symmetry (linear, trigonal-planer, tetrahedral) associated with sp, sp² and sp³ hybridization respectively.
- Draw a representation of a sigma bond and a pi bond between carbon atoms.
- Draw a molecular orbital representation of ethene (ethylene) labeling the bonds sigma, or pi respectively.
- Draw a molecular orbital representation of ethyne (acetylene) labeling the bonds sigma or pi as appropriate.
- Know the functional groups, IUPAC and common nomenclature.
- Review intermolecular forces.
- Know the alkyl groups containing 1-4 carbons.
- Identify functional groups found in a complicated structure

Unit 3 ORGANIC REACTIONS: ACIDS AND BASES [Supports SLO #1,2,3]

The student will be able to...

- Explain the terms mechanism, intermediate, heterolytic and homolytic bond cleavage, radical, carbocation and carbanion.
- Understand Bronsted-Lowry acid base theory and the Lewis definition of acids and bases.
- State the Arrhenius, Bronsted and Lewis definitions of acids and bases.

4. Give at least one example of an acid and of a base which do not meet the Bronsted definition, but which are in accord with the Lewis definition.
5. Illustrate carbocation and carbanion formation using equations and curved arrows.
6. Understand acid and base strength (K_a and pK_a).
7. Predict the outcome of acid-base reactions using curved arrows and the principle "Acid-base reactions always favor the formation of the weaker acid and the weaker base."
8. Describe the effect of structure, hybridization and solvent (aqueous and nonaqueous) on acidity
9. Explain the terms inductive effect and resonance effect.
10. Understand thermodynamics in a qualitative sense.
11. Explain and write a mechanism showing how an organic compound can act as a base.
12. Know how to synthesize deuterium and tritium-labeled compounds using acid-base principles.
13. Begin writing mechanisms in a separate one subject notebook (one mechanism per page).

Unit 4 ALKANES [Supports SLO #1,2,3]

The student will be able to...

1. Write the general molecular formula for any alkane.
2. Draw a molecular orbital representation of a simple alkane such as ethane or propane and label the kinds of bonds found between the atoms.
3. Name the C1 through C20 straight chain alkanes.
4. Write and correctly label the structures of the following alkyl groups: methyl, ethyl, propyl, isopropyl, butyl, isobutyl, sec-butyl, and tert-butyl.
5. Given a structure, name any given alkane using the IUPAC system of nomenclature or given an IUPAC name draw the corresponding structure.
6. Define the terms 1°, 2°, 3° carbon atoms and hydrogen atoms.
7. For any given alkane, label each of the carbon and hydrogen atoms as to whether they are 1°, 2°, 3°.
8. Know the names of the functional groups, generalized formulas and IUPAC nomenclature of compounds.
9. Predict the effect of increasing carbon number on the boiling point, density, and melting point of alkanes.
10. Predict the effect of carbon branching on the boiling point and melting point of alkane isomers of given carbon number.
11. State the major natural source of alkanes and discuss how and to what extent individual alkanes can be obtained from such a source or sources.
12. Write balanced equations for alkane synthesis, eg hydrogenation of an alkene and alkyne.
13. Draw structural formulas for the constitutional isomers of given a molecular formula
14. Define and illustrate the concept of homologs and homologous series as used in organic chemistry
15. Calculate the Index of Hydrogen Deficiency for hydrocarbons.
16. Apply heat of combustion to compound stability.

UNIT 5 CYCLOALKANES [Supports SLO #1,2,3]

The student will be able to...

1. Given a structure, name any given cycloalkane or given a name draw the corresponding structure
2. Explain what is meant by the conformation of a molecule
3. Describe and illustrate by means of Newman projections or "sawhorse" formulas what is meant by eclipsed, skew, and staggered conformations.
4. Analyze Newman representations of the anti, eclipsed, and gauche conformers of a given molecule with respect to stability.
5. Evaluate what factors cause a molecule to exist as one conformer as opposed to another
6. Analyze which conformations are the most stable and which are the least stable.
7. Compare and contrast the ease of formation and the reactivity of the three categories of cycloalkanes; (a) cyclopropane and cyclobutane; (b) cyclopentane and cyclohexane; and (c) cycloheptane and larger rings.
8. In terms of conformational stability, analyze the stabilities of the boat, chair, and twist conformations of cyclohexane.
9. Identify substituents on a cyclohexane ring as being axial or equatorial and indicate the preferred conformation.
10. Explain what is meant by the term 1,3-diaxial interaction and indicate what role it plays in the preferred conformation of substituted cyclohexanes.

11. Draw structures and write IUPAC names of bicyclic compounds.

UNIT 6 STEREOCHEMISTRY [Supports SLO #1,2,3]

The student will be able to...

1. State what is meant by the term stereoisomerism.
2. State what is meant by the configuration of a molecule.
3. Describe what is meant by plane polarized light.
4. Sketch the parts of a polarimeter, labeling each part, and describe how the polarimeter works
5. Given the appropriate experimental data, calculate the specific rotation of a compound.
6. Define the terms dextrorotatory and levorotatory and indicate what symbols are used for their designation.
7. Discuss factors involved in why some compounds show optical activity while others do not.
8. Define and illustrate the term enantiomers and give appropriate examples.
9. Define the term chirality (dissymmetry).
10. Discuss the relationship between chirality (dissymmetry) and enantiomerism
11. Discuss the relationship between enantiomers and optical activity
12. Define and illustrate the term chiral (asymmetric) carbon atom
13. Analyze the relationship between chiral (asymmetric) carbon atom, chirality (dissymmetry), enantiomerism and optical activity
14. Define the term racemic mixture of racemic modification.
15. Describe how a racemic mixture might be separated into its components.
16. Given the structure of a compound, classify its configuration as R or S
17. State the principal sequence rules used for R and S designation of configuration.
18. Define the term diastereomer.
19. Define the terms meso structure or meso compound and draw the structure of an appropriate example.
20. Differentiate between enantiomers and diastereomers.
21. Show, by suitable structures and equations, how a chiral (asymmetric) center can be introduced into a molecule
22. Explain and illustrate what is meant by the term optical purity.
23. Show, by means of suitable equations, how a second chiral (asymmetric) center can be formed in a molecule.
24. Show, by means of a suitable equation, how the reaction of a particular enantiomer can result in a product which is a racemic mixture.
25. Describe the role of diastereomerism in the resolution of racemic mixtures
26. State whether a given disubstituted cycloalkane can exist in diastereomeric, enantiomeric or meso form.

Unit 7 ALKYL HALIDES AND NUCLEOPHILIC ALIPHATIC SUBSTITUTION [Supports SLO #1,2,3]

The student will be able to...

1. Given the structure of an alkyl halide write an appropriate name or given a name draw the corresponding structure.
2. Write equations for at least three methods of preparing alkyl halides including at least one from alcohols; one from alkanes, or arenes; and one from alkenes or alkynes.
3. Write equations for at least three general reactions of alkyl halides.
4. Differentiate between first and second order kinetics of a reaction.]
5. Define what is meant by an SN1 and SN2 reaction and give an example of each
6. Define the terms enthalpy change and energy of activation
7. State and illustrate in terms of enthalpy changes ENDOTHERMIC and EXOTHERMIC reactions.
8. By means of a potential energy diagram, interpret the energy profile for an endothermic or an exothermic reaction indicating on the diagram the "role" of activation energy
9. Describe why an increase in reaction temperature might generally be expected to increase the rate of a chemical reaction.
10. Describe what is meant by the term TRANSITION STATE.
11. Analyze examples of what might be found in the transition state of various chemical reactions.

12. By means of suitable equations write the mechanism for an SN1 reaction, including the concepts of nucleophiles and leaving groups.
13. Explain why optical purity is lost in an SN1 reaction.
14. Given a list of alkyl halides, list them in decreasing order of reactivity toward SN1 reactions, explain.
15. Explain why and under what circumstances rearrangements may be observed in conjunction with SN1 reactions.
16. By means of a suitable equation write an illustrative mechanism of an SN2 reaction.
17. State what is meant by inversion of configuration in an SN2 reaction and by suitable structural formulas show how it comes about.
18. Explain how and why optical purity is maintained in an SN2 reaction.
19. State the relative importance of electronic and steric factors in SN2 reactions
20. Given a list of alkyl halides, list them in decreasing order of reactivity toward SN2 reactions.
21. List and explain what experimental variables can be manipulated to influence SN1 vs SN2 reactions eg. solvent.
22. Differentiate between the terms, STEREOSELECTIVE REACTIONS and STEREOSPECIFIC REACTIONS.
23. Define the terms carbocation and give an example.
24. List the carbocations (1°, 2°, 3°) in order of decreasing stability and account for these differences in stability.
25. Define the term inductive effect and give an example
26. Illustrate the rearrangement of carbocations via alkyl or hydride 1,2-shifts.

UNIT 8 E1 AND E2 REACTIONS [Supports SLO #1,2,3]

The student will be able to...

1. Write the mechanism for the dehydrohalogenation of an alkyl halide to form an alkene
2. Write a mechanism for an E1 reaction and list the experimental evidence for it.
3. Write the mechanism for an E2 reaction and list the experimental evidence supporting it.
4. By means of suitable "sawhorse" formulas or Newman projections, show how trans elimination is involved in E2 elimination reactions.
5. State and illustrate how the structure of the substrate can affect the nature of the products when elimination and substitution can be competing reactions.]
6. Understand the factors that influence the competition between substitution and elimination reactions.
7. By means of generalized structural formulas, prepare a list of alkenes in increasing order of stability or decreasing ease of formation.

UNIT 9 PREPARATION OF ALKENES [Supports SLO #1,2,3]

The student will be able to...

1. Write the general molecular formula for any alkene.
2. Draw a molecular orbital representation of a simple alkene such as ethene or propene and label the kinds of bonds found between the atoms.
3. Given a structure, name any given alkene using the IUPAC system of nomenclature, or given a IUPAC name draw the correct structure.
4. Define and give examples of geometric isomers.
5. Given a structure, label it correctly as the cis or trans isomer, or given the isomer name draw the correct structure.
6. Given a structure, label it correctly as the Z (zusammen) or E (entgegen) configuration, or given the isomer name, draw the correct structure
7. Write balanced equations for at least three methods of alkene synthesis.
8. Write the mechanisms for the dehydration of alcohols to alkenes (E1 /E2).
9. State carbocation stability and explain carbocation rearrangements.
10. Explain how Zaitsev's rule is used to predict the product of an elimination reaction.
11. Compare Zaitsev's rule and Hofmann's rule.

UNIT 10 REACTIONS OF ALKENES [Supports SLO #1,2,3]

The student will be able to...

1. Write balanced equations for at least five addition reactions of alkenes.
2. Define the terms electrophilic addition and electrophilic reagent.
3. State Markovnikov's rule and give examples showing its effect.
4. State what is meant by anti-Markovnikov addition and note the conditions under which it takes place
5. Write a mechanism for the electrophilic addition of electrophilic reagents to alkenes, including stereochemistry.
6. Write a mechanism which accounts for carbon skeleton rearrangement and isomer formation during the electrophilic addition of electrophilic reagents to alkenes
7. Write a mechanism which accounts for the addition of symmetrical reagents such as bromine or chlorine to alkenes.
8. Write a mechanism which accounts for the formation of halohydrins with the observed arrangement of substituents.
9. Explain the role played by the catalyst in the hydrogenation of alkenes.
10. Define the terms dimer and dimerization and write an equation for the dimerization reaction.
11. Write the mechanism for the acid-catalyzed dimerization of 2-methylbutene.
12. Use the principle of Retrosynthetic analysis to plan an organic synthesis.
13. Write the mechanism for an acid catalyzed addition reaction involving an alkene and alkyne
14. State what is meant by the term CIS (SYN) and TRANS (ANTI) addition to alkenes
15. State and give examples of how geometric isomerism of an alkene can affect the nature of the stereoisomers resulting from cis (syn) or trans (anti) addition to the alkene.
16. Give examples of reagents which add to alkenes mainly by cis (syn) addition and examples of those which add mainly by trans (anti) addition.
17. Use regioselective reactions in the synthesis of alcohols from alkenes (hydroboration, oxymercuration/demercuration).
18. Write a balanced equation for the cleavage reaction of an alkene with ozone and name, by general class, all the key intermediate compounds.
19. Write oxidation reactions using KMnO_4 and OsO_4 .
20. Describe simple chemical tests which can be used for the qualitative identification of an alkene and write equations for the reactions involved.
21. Describe tests for alkanes, alkynes, alkyl halides and alcohols.
22. Define the term carbene and give an example
23. Use carbene and Simmons-Smith reactions for cyclopropane synthesis.

UNIT 11 ALKYNES [Supports SLO #1,2,3]

The student will be able to...

1. Write the general molecular formula for any alkyne.
2. Draw a molecular orbital representation of a simple alkyne and label the kinds of bonds found between the atoms.
3. Given a structure, name any given alkyne using the IUPAC system of nomenclature, or given an IUPAC name draw the correct structure.
4. Write balanced equations for at least two methods of alkyne synthesis
5. Explain why the hydrogen atom on the first carbon atom of a terminal alkyne is more acidic than the hydrogen atom of an alkane
6. Describe, illustrate with suitable equations, and name any relevant catalyst used to reduce alkynes to cis or trans alkenes.
7. Compare and contrast substitution vs. elimination reactions of sodium acetylide with alkyl halides, indicating which halides are most easily substituted, and which are more likely to undergo elimination reactions.
8. Write bromine and chlorine addition reactions with alkynes.
9. Write hydrogen halide addition reactions with alkynes (regioselectivity).

UNIT 12 – RADICAL REACTIONS [Supports SLO #1,2,3]

The student will be able to...

1. Define bond dissociation energy and indicate how it differs from bond energy
2. Write a balanced equation for the stepwise chlorination of methane showing the successive replacement of one, two, three, and four hydrogen atoms.]

3. Define the term free radical and give an example.
4. State what is meant by a chain reaction.
5. State what is meant by CHAIN-INITIATING, CHAIN PROPAGATING, and CHAIN TERMINATING steps in a reaction.
6. Show, by suitable balanced equations, an example of a chain reaction indicating the chain-initiation, chain propagation, and chain termination steps
7. State what is meant by a reaction inhibitor
8. Write a balanced equation for the halogenation of an alkane noting the conditions under which it would typically be performed.
9. Write equations outlining the mechanism by which the halogenation of alkanes will normally proceed.
10. Given the relative rates of reaction of 1°, 2°, and 3° hydrogen atoms, predict the isomer distribution resulting from the chlorination of an alkane.
11. Explain why bromination of alkanes, which is much slower, is much more selective than chlorination with respect to isomer formation.
12. Show, by means of an appropriate equation, how cyclopropane derivatives can be made by means of methylene insertion reactions.
13. Write a mechanism for the free radical addition reaction to alkenes using hydrogen bromide; bromine or chlorine; or compounds such as CHCl₃ and CBrCl₃ serving as the reagent being added.
14. Define the terms monomer, polymer.

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, 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 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.