



CHEM 210 - ORGANIC CHEMISTRY I

Units Lecture	3.00	Units Lab	2.00	Units Total	5.00
Total Hrs Lecture	49.50	Total Hrs Lab	99.00	Total Course Hrs	148.50

COURSE DESCRIPTION

This course is the first semester in a standard one-year organic chemistry sequence for students majoring in chemistry and other sciences. Topics covered include the structure and reactions of alkanes, alkenes, alkynes, alkyl halides, alcohols, ethers, and dienes; determination of structure by physical and chemical methods; and organic chemistry lab techniques. Students discuss aromatic compounds, structure, nomenclature, and reactions. The course emphasizes reaction mechanisms of organic chemical reactions and predicting products.

ENROLLMENT RESTRICTIONS

PREREQUISITES

CHEM 110 with a grade of "C" or better.

COREQUISITES

ADVISORIES

CHEM 111.

OUTLINE OF COURSE CONTENT

The course will address the following topics:

Lecture:

- I. Chemical bonding
 - A. Atoms, electrons, and orbitals
 - B. Ionic bonds
 - C. Covalent bonds
 - D. Multiple bonding in Lewis structures
 - E. Polar covalent bonds and electronegativity
 - F. Formal charge
 - G. Writing structural formulas of organic molecules
 - H. Constitutional isomers
 - I. Resonance
 - J. The shapes of some simple molecules
 - K. Molecular dipole moments
 - L. Molecular orbitals of the hydrogen molecule
 - M. sp³ hybridization and bonding in methane
 - N. sp³ hybridization and bonding in ethylene
 - O. sp³ hybridization and bonding in acetylene
 - P. Which theory of chemical bonding is best?

- II. Alkanes
 - A. Classes of hydrocarbons
 - B. Functional groups in hydrocarbons
 - C. Functionally substituted derivatives of alkanes
 - D. Carbonyl-containing functional groups
 - E. Introduction to alkanes: methane
 - F. Ethane and propane
 - G. Isomeric alkanes: the butanes
 - H. Higher n-alkanes
 - I. C₅H₁₂ isomers
 - J. Systematic IUPAC nomenclature of unbranched alkanes
 - K. Applying the IUPAC Rules: the names of the C₆H₁₄ isomers
 - L. Alkyl groups
 - M. IUPAC names of highly branched alkanes
 - O. Cycloalkane nomenclature
 - P. Sources of alkanes and cycloalkanes
 - Q. Physical properties of alkanes and cycloalkanes



- R. Chemical properties, combustion of alkanes thermochemistry
- S. Oxidation-reduction in organic chemistry.

III. Conformations of alkanes and cycloalkanes

- A. Conformational analysis of ethane
- B. Internal rotation in ethane
- C. Conformational analysis of butane
- D. Conformations of higher alkanes
- E. The shapes of cycloalkanes: planar or nonplanar?
- F. Conformations of cyclohexane
- G. Axial and equatorial bonds in cyclohexane
- H. Conformational inversion (ring flipping) in cyclohexane
- I. Conformational analysis of monosubstituted cyclohexanes
- J. Small rings: cyclopropane and cyclobutane
- K. Cyclopentane
- L. Medium and large rings
- M. Disubstituted cycloalkanes, stereoisomers
- N. Conformational analysis of disubstituted cyclohexanes
- O. Polycyclic ring systems
- P. Heterocyclic compounds.

IV. Alcohols and alkyl halides

- A. IUPAC nomenclature of alkyl halides
- B. IUPAC nomenclature of alcohols
- C. Classes of alcohols and alkyl halides
- D. Bonding in alcohols and alkyl halides
- E. Physical properties of alcohols and alkyl halides
- F. Acids and bases: general principles
- G. Acid-base reactions: a mechanism for proton transfer
- H. Acidity of alcohols, alkoxide ions
- I. Preparation of alkyl halides from alcohols and hydrogen halides
- J. Mechanism of the reaction of alcohols with hydrogen halides
- K. Structure, bonding, and stability of carbocations
- L. Potential energy diagrams for multistep reactions, the SN1 Mechanism
- M. Effect of alcohol structure in reaction rate
- N. Reaction of primary alcohols with hydrogen halides, the SN2 Mechanism
- O. Other methods for converting alcohols to alkyl halides
- P. Halogenation of alkanes
- Q. Chlorination of methane
- R. Structure and stability of free radicals
- S. Mechanism of methane chlorination
- T. Halogenation of higher alkanes, regioselectivity.

V. Structure and preparation of alkenes, elimination reactions

- A. Alkene nomenclature
- B. Structure and bonding in alkenes
- C. Isomerism in alkenes
- D. Naming stereoisomeric alkenes by the E-Z Notational System
- E. Physical properties of alkenes
- F. Relative stabilities of alkenes
- G. Sources of strain in cycloalkenes
- H. Preparation of alkenes: elimination reactions
- I. Dehydration of alcohols



- J. Regioselectivity in alcohol dehydration: the Zaitsev Rule
- K. Stereoselectivity in alcohol dehydration
- L. The mechanism of acid-catalyzed dehydration of alcohols
- M. Rearrangements in alcohol dehydration
- O. Dehydrohalogenation of alkyl halides
- P. Mechanism of the dehydrohalogenation of alkyl halides: the E2 mechanism
- Q. Anti-elimination in E2 reactions: stereoelectronic effects
- R. A different mechanism for alkyl halide elimination: the E1 mechanism.

VI. Reactions of alkenes: addition reactions

- A. Hydrogenation of alkenes
- B. Heats of hydrogenation
- C. Stereochemistry of alkene hydrogenation
- D. Electrophilic addition of hydrogen halide to alkenes
- E. Regioselectivity of hydrogen halide addition: Markovnikov's Rule
- F. Mechanistic basis for Markovnikov's Rule
- G. Carbocation rearrangements in hydrogen halide addition to alkenes
- H. Free-radical addition of hydrogen bromide to alkenes
- I. Addition of sulfuric acid to alkenes
- J. Acid-catalyzed hydration of alkenes
- K. Hydroboration-oxidation of alkenes
- L. Stereochemistry of hydroboration-oxidation
- M. Mechanism of hydroboration-oxidation
- N. Addition of halogens to alkenes
- O. Stereochemistry of halogen addition
- P. Mechanism of halogen addition to alkenes, halonium ions
- Q. Conversion of alkenes to vicinal halohydrins
- R. Epoxidation of alkenes
- S. Ozonolysis of alkenes
- T. Analysis of alkenes: molecular formula as a clue to structure
- U. Reactions of alkenes with alkenes, polymerization
- V. Introduction to organic chemical synthesis.

VII. Stereochemistry

- A. Molecular chirality, enantiomers
- B. The Stereogenic center
- C. Symmetry in achiral structure
- D. Properties of chiral molecules: optical activity
- E. Absolute and relative configuration
- F. The Cahn-Ingold-Prelog R-S Notational System
- G. Fischer projection formulas
- H. Physical properties of enantiomers
- I. Reactions that create a stereogenic center
- J. Chiral molecules with two stereogenic centers
- K. Achiral molecules with two stereogenic centers
- L. Molecules with multiple stereogenic centers
- M. Reactions that produce diastereomers
- N. Resolution of enantiomers
- O. Stereoregular polymers
- P. Stereogenic centers other than carbon.

VIII. Nucleophilic substitution

- A. Functional group transformation by nucleophilic substitution



- B. Substitution of one halogen by another
- C. Relative reactivity of halide leaving groups
- D. Bimolecular (SN2) mechanism of nucleophilic substitution
- E. Stereochemistry of SN2 reactions
- F. How SN2 reactions occur
- G. Steric effects in SN2 reactions
- H. Nucleophiles and nucleophilicity
- I. Unimolecular (SN1) mechanism of nucleophilic substitution
- J. Carbocation stability and the rate of substitution by the SN1 mechanism
- K. Stereochemistry of SN1 reactions
- L. Carbocation rearrangements in SN1 reactions
- M. Effect of solvent on the rate of nucleophilic substitution
- N. Substitution and elimination as competing reactions
- O. Sulfonate esters as substrates in nucleophilic substitution
- P. A retrospective look: reactions of alcohols with hydrogen halides.

IX. Alkynes

- A. Sources of alkynes
- B. Nomenclature
- C. Structure and bonding in alkynes, sp hybridization
- D. Cycloalkynes
- E. Physical properties of alkynes
- F. Acidity of acetylene and terminal alkynes
- G. Preparation of alkynes by alkylation of acetylene and terminal alkynes
- H. Preparation of alkynes by elimination reactions
- I. Reactions of alkynes
- J. Hydrogenation of alkynes
- K. Metal-ammonia reduction of alkynes
- L. Addition of hydrogen halides to alkynes
- M. Hydration of alkynes
- O. Addition of halogens to alkynes
- P. Ozonolysis of alkynes.

X. Conjugation in alkadienes and allylic systems

- A. The allyl group
- B. Allylic carbocations
- C. Allylic free radicals
- D. Allylic halogenation
- E. Classes of dienes
- F. Relative stabilities of alkadienes
- G. Electron delocalization in conjugated dienes
- H. Bonding in allenes
- I. Preparation of dienes
- J. Addition of hydrogen halides to conjugated dienes
- K. Halogen addition to dienes
- L. Diels-Alder reaction
- M. Stereoselectivity of Diels-Alder reactions
- N. Electrocyclic reactions of polyenes
- O. p molecular orbitals of alkenes and conjugated polyenes
- P. p molecular orbital analysis of the Diels-Alder reaction
- Q. p molecular orbital analysis of electrocyclic reactions.

XI. Arenes and aromaticity



- A. Benzene
 - B. Benzene reactivity
 - C. Kekule's formulation of the benzene structure
 - D. Structural features of benzene
 - E. A resonance description of bonding in benzene
 - F. Stability of benzene
 - G. Orbital hybridization model of bonding in benzene
 - H. p molecular orbitals of benzene
 - I. Substituted derivatives of benzene and their nomenclature
 - J. Polycyclic aromatic hydrocarbons
 - K. Physical properties of arenes
 - L. Reactions of arenes: a preview
 - M. Birch Reduction
 - N. Free-radical halogenation of alkylbenzenes
 - O. Oxidation of alkylbenzenes
 - P. Nucleophilic substitution in benzylic halides
 - Q. Preparation of alkenylbenzenes
 - R. Addition reactions of alkenylbenzenes
 - S. Polymerization of styrene
 - T. Cyclobutadiene and cyclooctatetraene
 - U. Hückel's Rule, annulenes
 - V. Aromatic ions
 - W. Heterocyclic aromatic compounds
 - X. Heterocyclic aromatic compounds and Hückel's Rule.
- XII. Reactions of arenes, electrophilic aromatic substitution
- A. Representative eElectrophilic aromatic substitution reactions of benzene
 - B. Mechanistic principles of electrophilic aromatic substitution
 - C. Nitration of benzene
 - D. Sulfonation of benzene
 - E. Halogenation of benzene
 - F. Friedel-Crafts alkylation of benzene
 - G. Friedel-Crafts acylation of benzene
 - H. Synthesis of alkylbenzenes by acylation-reduction
 - I. Rate and orientation in electrophilic aromatic substitution
 - J. Rate and orientation in the nitration of toluene
 - K. Rate and orientation in the nitration of (trifluoromethyl)benzene
 - L. Substituent effects in electrophilic aromatic substitution: activating substituents
 - M. Substituent effects in electrophilic aromatic substitution: deactivating substituents
 - N. Substituent effects in electrophilic aromatic substitution: halogen substituents
 - O. Multiple substituent effects
 - P. Regioselective synthesis of disubstituted aromatic compounds
 - Q. Substitution in naphthalene
 - R. Substitution in heterocyclic aromatic compounds.
- XIII. Spectroscopy
- A. Principles of molecular spectroscopy: electromagnetic radiation
 - B. Principles of molecular spectroscopy: quantized energy states
 - C. Proton magnetic resonance (^1H NMR) spectroscopy
 - D. Nuclear shielding and chemical shift
 - E. How chemical shift is measured
 - F. Chemical shift and molecular structure
 - G. Interpreting proton NMR spectra



- H. Spin-spin splitting in NMR spectroscopy
- I. Patterns of spin-spin splitting: the ethyl group
- J. Patterns of spin-spin splitting: the isopropyl group
- K. Patterns of spin-spin splitting: pairs of doublets
- L. Geminal coupling
- M. Complex splitting patterns
- N. Proton NMR spectra of alcohols
- O. NMR and conformations
- P. Carbon-13 nuclear magnetic resonance: the sensitivity problem
- Q. Carbon-13 nuclear magnetic resonance: interpretation of spectra
- R. Infrared spectroscopy
- S. Ultraviolet-visible (UV-VIS) spectroscopy
- T. Mass spectrometry, gas chromatography, GC/MS, and MS/MS.

Laboratory:

Laboratory investigations are designed to be hands on, collaborative activities that support and complement accompanying lecture theories. All topics addressed in lecture are applied and extended in the lab component. In addition, the lab component addresses the following.

- I. VSEPR and molecular models
- II. Separations of solids and liquids
- III. Recrystallization and melting points
- IV. Chromatography 1: thin-layer chromatography
- V. ChemDraw and Chem3D molecular modelling
- VI. Chromatography 2: gas chromatography
- VII. Liquids: distillation, boiling points and the fermentation and distillation of ethanol
- VIII. Elimination Reactions: acid-catalyzed dehydration of 2-pentanol
- IX. Fischer Esterification: preparation of isopentyl acetate (isoamyl acetate)
- X. Second order nucleophilic substitution: the preparation of 1-bromobutane from 1-butanol
- XI. Diels-Alder Cycloaddition: the reaction of cyclopentadiene with maleic anhydride
- XII. Electrophilic aromatic substitution: nitration of ethyl benzoate

PERFORMANCE OBJECTIVES

Upon successful completion of this course, students will be able to do the following:

- 1). Predict the outcome of organic chemical reactions, based on analyzing the structures of the reactants and conditions of the reaction
- 2). Identify the reagents necessary to carry out organic chemical transformations and syntheses as well as predicting products of reaction
- 3). Show the mechanisms of organic chemical reactions
- 4). Determine the structure of organic compounds using physical and chemical methods of analysis
- 5). Carry out organic chemical reactions and separations in the laboratory followed by a characterization of the reaction products
- 6). Explain the structure and reactivity of organic compounds in terms of bonding theories and electronic structure
- 7). Demonstrate how different functional groups contribute to reactivity and identify the type of compounds they can be chemically converted into



- 8). Demonstrate characteristic substitution reactions are performed and how products can be characterized.

READING ASSIGNMENTS

Reading assignments will be consistent with, but not limited by, the following types and examples:

- 1). Read the appropriate textbook sections to be discussed in lecture. Reading chapter material prior to lecture introduces the student to relevant terminology, structures and names of compounds, and reaction mechanisms
- 2). Read laboratory experiments in order to prepare laboratory notebook prior to coming to lab. Experiments are performed according to procedures written in laboratory notebook
- 3). Read supplemental material for labs including knowing safety considerations based on available MSDS (Material Safety Data Sheets) for all chemicals used in the laboratory
- 4). Read articles from scientific journals, magazines, and reliable Internet sites relevant to current lecture material and labs.

WRITING ASSIGNMENTS

Writing assignments will be consistent with, but not limited by, the following types and examples:

- 1). Prepare short written responses to homework assignments that require analysis and/or assimilation of facts based on textbook readings and/or lecture content
- 2). Document laboratory exercises as written notebook entries while performing each lab activity. After experiment is completed, students write a results and discussion section in their notebook describing what was accomplished during the experiment. A conclusions section for each experiment includes addressing the objectives of the experiment and how this experiment has accomplished those objectives
- 3). Prepare four formal written lab reports in scientific journal article format, with references, for selected experiments during the semester.

OUTSIDE-OF-CLASS ASSIGNMENTS (READING/WRITING/OTHER)

Outside-of-class assignments will be consistent with, but not limited by, the following types and examples:

- 1). Complete extensive reading of textbook for every section covered during lecture
- 2). Read experimental protocols and write laboratory notebook prior to coming to lab
- 3). Read and understand supplemental experimental material including MSDS and techniques to be followed during lab
- 4). Perform homework assignments using problems in the text and at the end of every chapter until competency is achieved
- 5). Prepare at least four formal written lab reports in scientific journal format for experiments performed during the semester
- 6). Study for exams, including essay questions requiring definitions, reactions, and interpretation of chemical phenomena.

STUDENT LEARNING OUTCOMES

<i>Learning Outcome</i>	<i>Mode of Assessment</i>
1. Students will analyze and interpret the periodic table to predict and explain differences in the reaction rates for standard substitution reactions.	1. Written essay question on exam, including cause and effect reasoning. Students will be given a periodic table, and instructed to rank a series of compounds in order of increasing reaction rates and explain the ranking trend.
2. Students will use knowledge of intermolecular forces and molecular structures to analyze, predict and explain differences in the boiling points and the existence of a trend.	2. Written essay question on exam, including cause and effect reasoning. Students will be given a series of constitutional isomers and instructed to rank them in order of increasing boiling points and explain the ranking trend.
3. Students will use knowledge of acid-base concepts and reactivity of organometallic compounds to analyze and explain appropriate conditions in which these substances are to be kept before certain specific reactions.	3. Written essay question on exam, including cause and effect reasoning. Students will be given an organometallic compound like a Grignard reagent and instructed to explain why it should be kept dry and free of some common chemicals before certain reactions.

METHODS OF INSTRUCTION

Instructional methodologies will be consistent with, but not limited by, the following types or examples:

- 1). Lecture presentation and classroom discussions using the language of chemistry covering the assigned sections from each chapter
- 2). In-class discussion and review of previously covered material solving problems on the board in individual or group



activity

3). Question and answer sessions for related chemical processes especially as they relate to every-day life.

METHODS OF EVALUATION

Evaluation methodologies will be consistent with, but not limited by, the following types or examples:

- 1). Questions on exams are designed to reflect critical and creative thinking using essay-type exams
- 2). Quizzes are given weekly covering material recently discussed during lecture to get immediate feedback on understand of new material
- 3). Laboratory notebooks containing pre-lab questions, procedures used to perform the experiment, and results of the experiment
- 4). At least four formal written lab reports using approved scientific journal article format with references
- 5). Homework problems solved to achieve competency from within each chapter
- 6). Problem solving or skill demonstrations
- 7). Proper understanding for and exercising of correct safety practices in the laboratory
- 8). High level of performance in the laboratory, including coming to the lab prepared, mastering lab techniques, and using the laboratory equipment properly.

REQUIRED TEXTBOOKS

Examples of typical textbooks for this course include the following:

- 1). Carey, Francis A., and Robert M. Giuliano. Organic Chemistry. 8th ed., McGraw Hill, 2011. ISBN: 978-0073402611
- 2). Bruice, Paula Yurkanis. Organic Chemistry. 6th ed., Prentice Hall, 2010. ISBN: 978-0321663139
- 3). Solomons, T. W. Graham, and Craig B. Fryhle. Organic Chemistry. 10th ed., Wiley, 2009. ISBN: 978-0470401415
- 4). Zubrick, James W. The Organic Chem Lab Survival Manual: A Student's Guide to Techniques. 8th ed., Wiley, 2010. ISBN: 978-0470494370.

OTHER REQUIRED INSTRUCTIONAL MATERIALS

- 1). Safety goggles
- 2). Quadrille notebook for lab
- 3). Chemical resistant gloves
- 4). Scientific non-graphing calculator.

COURSE REPEATABILITY

Total Completions Allowed:

1

In Combination With: