ILLINOIS VALLEY COMMUNITY COLLEGE

COURSE OUTLINE

DIVISION: Natural Sciences & Business

COURSE: CHM 2003 Organic Chemistry II

Date: Spring 2023

Credit Hours: 5

Complete all that apply or mark "None" where appropriate:

Prerequisite(s): CHM 2002

Enrollment by assessment or other measure? ☐ Yes ☒ No
If yes, please describe:

Corequisite(s): None

Pre- or Corequisite(s): None

Consent of Instructor: ☐ Yes ☒ No

Delivery Method:		
☒ **Lecture**	**3 Contact Hours**	**(1 contact = 1 credit hour)**
☒ **Seminar**	**1 Contact Hours**	**(1 contact = 1 credit hour)**
☒ **Lab**	**3 Contact Hours**	**(2-3 contact = 1 credit hour)**
☐ **Clinical**	**0 Contact Hours**	**(3 contact = 1 credit hour)**

Offered: ☐ **Fall** ☒ **Spring** ☐ **Summer**

CATALOG DESCRIPTION and IAI NUMBER (if applicable):
This course is a continuation of Organic Chemistry I and includes applications of mechanisms to synthetic reactions, the use of special data in the determination of structure and analysis, and natural products. **IAI Equivalent: CHM 914**

ACCREDITATION STATEMENTS AND COURSE NOTES:
None

COURSE TOPICS AND CONTENT REQUIREMENTS:

1. Ethers and epoxides, thiols and sulfides
    a. Nomenclature, structure, properties
    b. Crown ethers
    c. Preparation of ethers and epoxides
    d. Reactions of ethers and epoxides
    e. Thiols and sulfides
    f. Synthesis strategies
2. Infrared Spectroscopy
    a. Theory behind IR
    b. Signal characteristics: wavenumber, intensity, shape
    c. Analyzing an IR spectrum
3. Nuclear Magnetic Resonance Spectroscopy
    a. Theory behind NMR
    b. Signal characteristics: chemical shift, integration, multiplicity
    c. Analyzing a proton NMR spectrum
    d. Analyzing a ^{13}C NMR spectrum
4. Mass Spectrometry
    a. Theory behind Mass Spectrometry
    b. Analyzing the peaks: $(M)^{+*}$, $(M+1)^{+*}$, $(M+2)^{+*}$, fragments
5. Conjugated Pi Systems and Pericyclic Reactions
    a. Classes of dienes
    b. Conjugated dienes
    c. MO theory
    d. Electrophilic addition
    e. Thermodynamic control vs. kinetic control
    f. Introduction to pericyclic reactions
    g. Diels-Alder reactions
    h. MO description of cycloadditions
    i. Electrocyclic reactions
    j. Sigmatropic rearrangements
6. Aromatic compounds
    a. Nomenclature, structure, stability
    b. Reactions at the benzylic position
    c. Reduction of the aromatic moiety
7. Aromatic Substitution Reactions
    a. Halogenation
    b. Sulfonation
    c. Nitration
    d. Friedel-Crafts alkylation and acylation
    e. Activating and deactivating groups
    f. Multiple substituents
    g. Synthesis strategies

8. Aldehydes and ketones
    a. Nomenclature
    b. Preparing aldehydes and ketones
    c. Reactions with nucleophiles: oxygen, nitrogen, carbon
    d. Baeyer-Villager oxidation
    e. Synthesis strategies
9. Carboxylic Acids and Their Derivatives
    a. Nomenclature, structure, and properties
    b. Preparation of carboxylic acids
    c. Reactions of carboxylic acids
    d. Reactivity of carboxylic acid derivatives
    e. Preparation and reactions of acid chlorides and acid anhydrides
    f. Preparation and reactions of esters
    g. Preparation and reactions of amides
    h. Preparation and reactions of nitriles
    i. Synthesis strategies
10. Alpha-carbon chemistry: Enols and Enolates
    a. Alpha-halogenation of enols and enolates
    b. Aldol reactions
    c. Claisen condensation
    d. Alkylation of the alpha position
    e. Conjugate addition reactions
    f. Synthesis strategies
11. Amines
    a. Nomenclature, structure, and properties
    b. Preparation of amines
    c. Reactions of amines
    d. Synthesis strategies
    e. Nitrogen heterocycles

INSTRUCTIONAL METHODS:

1. Lecture
2. Discussion
3. Problem solving
4. Reading assignments
5. Written assignments
6. Individual instruction in the laboratory
7. Experiments
8. Use of computers

Grades are based on a standard scale of
90 - A
80 - B
70 - C
60 - D
below 60 - F

INSTRUCTIONAL MATERIALS:
Textbooks:
Organic Chemistry, Klein, David: Wiley
Molecular model kits

Resources
CRC Handbook of Chemistry and Physics (Available in the Lab and the Library)
Aldrich Library of FTIR Spectra (Available in the Lab)
CRC Handbook of Organic Compounds (Available in the Lab**)**

LEARNING OUTCOMES AND GOALS:
Institutional Learning Outcomes
☐ 1) Communication – to communicate effectively;
☒ 2) Inquiry – to apply critical, logical, creative, aesthetic, or quantitative analytical reasoning to formulate a judgement or conclusion;
☐ 3) Social Consciousness – to understand what it means to be a socially conscious person, locally and globally;
☐ 4) Responsibility – to recognize how personal choices affect self and society.

Course Outcomes and Competencies
Outcome 1 - Students will be able to interpret spectral data in relation to the structure and functional groups of a compound.
Competency 1.1 Given the names or structural formula of a hydrocarbon, students will be able to:
A. determine the numbers of non-equivalent protons that could give rise to NMR absorptions.
B. determine what the relative peak areas would be for these protons.
C. using a table of characteristic proton chemical shifts, determine the approximate S values for the protons.
Competency 1.2 Students will be able to determine the structure of hydrocarbon given the NMR data for the compound using a table of characteristic proton chemical shifts and a table of characteristic coupling constants.
Competency 1.3 Given an IR spectrum and a table of characteristic group frequencies, students will be able to determine which of the following functional groups are present in a compound: alkanes, alkenes, alkynes, alcohols, ethers, alkyl halides, aldehydes, ketones, carboxylic acids.
Outcome 2 - Students will be able to explain the stability, reactions and reaction products of allylic and conjugated compounds.
Competency 2.1 Explain the stability and reaction products of allylic systems such as allylic cations, anions, and radicals and the reactions on conjugated dienes or trienes in terms of resonance structures and resonance theory.
Competency 2.2 Students will be able to explain the kinetic versus thermodynamic control of addition reactions of dienes (1,2 and 1,4 addition) by means of a reaction coordinate energy profile diagram and using the rules for carbonium stability (resonance theory) and alkene stability.
Competency 2.3 Students will be able to give the special reactions of unsaturated carbonyl compounds such as isomerization of the double bond and 1,2 and 1,4 additions.

Competency 2.4 Students will be able to give the reactants for preparing cyclohexane ring systems by reduction of benzene derivative and the Diels-Alder reaction.

Competency 2.5 Students will be able to recognize and identify the isoprene unit as it may exist in a terpene or steroid.

Outcome 3 - Students will be able to explain the resonance energy of benzene, predict when aromatic stability prevails, give mechanisms and name products of electriphilic aromatic substitutions and explain their orientation.

Competency 3.1 Students will be able to show how the resonance energy of benzene is calculated and explained.

Competency 3.2 Students will be able to apply the 4n + 2 rule to predict aromatic stability.

Competency 3.3 Students will be able to write the mechanisms for the following electrophilic substitution reactions on benzene: bromination, sulfonation, nitration, protonation, Friedel-Crafts acylation

Competency 3.4 Students will be able to name substituted benzenes given structures or draw structures if given the name.

Competency 3.5 Students will be able to give the orientation of substituted benzenes in electrophilic aromatic substitution reactions.

Competency 3.6 Students will be able to show how theory can explain the orientation effects in electrophilic aromatic substitutions.

Competency 3.7 Students will be able to give the mechanism for and explain the limitations of the Friedel-Crafts alkylation reaction.

Outcome 4 - Students will be able to give mechanisms for the substitution of halogens for the production of halobenzen and explain the reactivity of aromatic side chain halides.

Competency 4.1 Students will be able to give the two mechanisms of substitution of halogen on halobenzenes.

Competency 4.2 Students will be able to predict and explain the reactivity of different aromatic side chain halogen compounds.

Outcome 5 - Students will be able to give equations for the preparation of organometallic compounds and their reaction with water.

Competency 5.1 Students will be able to give the equations for the preparation of organometallic compounds from alkyl halides or metal exchange with other organometallics.

Competency 5.2 Students will be able to give the equations and products of reaction of the organometallic compounds with water for metals with an electronegativity of 1.7 or less.

Competency 5.3 Students will be able to predict the direction of an organometallic-metal exchange reaction from a table of standard reduction potentials.

Outcome 6 - Students will be able to name or give the structure of aldehydes and ketones, give the equations and some mechanisms for the production and reactions of aldehydes and ketones giving special attention to oxidation-reduction reactions including the reagents involved.

Competency 6.1 Students will be able to name an aldehyde or ketone given its structures or give a correct structure given a name.

Competency 6.2 Students will be familiar with the methods to write equations for the following transformations of groups into aldehydes or ketones.

A. Oxidation of alcohols

B. Oxidation of alkenes
C. Hydration of alkynes

Competency 6.3 Students will be able to give the equations for the reactions of aldehydes and ketones which are explained in terms of keto-enol equilibria or an enolate ion and give the theoretical explanation for the acidity of alpha-hydrogens of aldehydes and ketones.

Competency 6.4 Student will be able to write a mechanism for the following kinds of carbonyl addition reactions:
A. formation of gem diols
B. hemiacetal and acetal formation
C. formation of imines and related compounds
D. simple additions such as acetylide ions, hydrogen cyanide
E. the aldol condensation

Competency 6.6 Given the reagents and conditions, students will be able to give the products of the major addition reactions or carbonyl compounds.

Competency 6.7 Students will be able to give the reagents, conditions and the products for the following kinds of oxidation and reduction reactions of ketones and aldehydes.
A. Baeyer-Villiger oxidation
B. Cannizzaro reaction and crossed Cannizzaro
C. Wolff-Kishner reduction
D. Clemmensen reduction
E. metal hydride reduction

Competency 6.8 Students will be able to recognize the different oxidizing and reducing agents and their resultant reaction with aldehydes and ketones.

Outcome 7 - Students will be able to give the IUPAC name, the common name and/or structure of carboxylic acids and their derivatives as well as the reactions and mechanisms which produce them or are undergone by them.

Competency 7.1 Students will be able to give the IUPAC name for carboxylic acids and the common name for any acid containing up to 5 carbons, if given the structure; or give the structure if given the name.

Competency 7.2 Students will be able to predict the effect on acidity of a carboxylic acid with a change in structure. Predict which of two different carboxylic acids would be the more acidic.

Competency 7.3 Students will be able to give the equations and/or reagents for the preparations of carboxylic acids from alkyl halides or alcohols by the methods of:
A. hydrolysis of nitriles
B. carbonation of organometallics
C. oxidation of primary alcohols

Competency 7.4 Students will be able to give the equations and/or reagents for the following reactions of carboxylic acids:
A. with base or diazomethane
B. Hell, Volhard-Zelinsky reaction
C. formation of amides
D. reduction
E. formation of esters
F. formation of acyl halides

Competency 7.5 Students will be able to give the correct names for the following derivatives of carboxylic acids: esters, anhydrides, amides, nitriles, acyl halides.

They will be able to give the correct structures of those derivatives, and also of sulfonates, sulfates, phosphates, phosphonates, phosphatidic acids.

Competency 7.6 Students will be able to give a correct mechanism for the nucleophilic substitution reactions of the carboxylic acid derivatives and to know the relative reactivities of these derivatives with nucleophiles.

Competency 7.7 Students will be able to give the correct products in the reactions of carboxylic acid and derivatives for the following reaction types:

A. hydrolysis
B. with alcohols
C. with amines or ammonia
D. with carboxylic acids or carboxylate salts
E. with organometallics
F. reducing agents

Competency 7.8 Students will be able to give correct products for the following:

A. Hofmann degradation
B. Pyrolytic eliminations of esters and xanthate esters

Outcome 8 - Students will be able to give the name, structure, properties, biological importance and reactions of various amines and amides.

Competency 8.1 Students will be able to give the IUPAC nomenclature of simple amines and amides, or, given the name, sketch the structure.

Competency 8.2 Students will be able to recognize the basicity properties and character of amines in chemical reactions.

Competency 8.3 Students will be able to give the general nucleophilic substitution reactions of amines.

Competency 8.4 Students will be able to write chemical equations for the following methods of preparation of amines:

A. reduction of nitro compounds
B. reduction of amides, oximes, and nitriles
C. Hofmann rearrangement or degradation

Competency 8.5 Students will be able to give the reactions of amines with nitrous acid and the coupling reactions of diazonium salts.

Outcome 9 - Students will be able to give the four major biological molecules, their general structure and their properties.

Competency 9.1 Students will be able to state the four major biomolecules: carbohydrates, lipids, amino acids, and nucleic acids

Competency 9.2 Students will be able to give the general structure and properties for each of the above.

Competence 9.3 Students will be able to give the nomenclature of simple carbohydrates.

Competency 9.4 Students will be able to give the hydrolysis reactions and general synthesis of carbohydrates, lipids, and proteins.