

Course: Organic Chemistry

PEIMS Code: N1120027

Abbreviation: ORGCHEM

Number of credits that may be earned: 1/2-1

Brief description of the course (150 words or less):

Organic chemistry is an introductory course that is designed for the student who intends to continue future study in the sciences. The student will learn the concepts and applications of organic chemistry. Topics covered include aliphatic and aromatic compounds, alcohols, aldehydes, ketones, acids, ethers, amines, spectra, and stereochemistry. A brief introduction into biochemistry is also provided. The laboratory experiments will familiarize the student with the important laboratory techniques, specifically spectroscopy.

Traditional high school chemistry courses focus on the inorganic aspects of chemistry whereas organic chemistry introduces the student to organic compounds and their properties, mechanisms of formations, and introduces the student to laboratory techniques beyond the traditional high school chemistry curriculum.

Essential Knowledge and Skills of the course:

- (a) General requirements. This course is recommended for students in Grades 11-12. The recommended prerequisite for this course is AP Chemistry.
- (b) Introduction. Organic chemistry is designed to introduce students to the fundamental concepts of organic chemistry and key experimental evidence and data, which support these concepts. Students will learn to apply these data and concepts to chemical problem solving. Additionally, students will learn that organic chemistry is still evolving by reading about current breakthroughs in the field. Finally, students will gain appreciation for role that organic chemistry plays in modern technological developments in diverse fields, ranging from biology to materials science.
- (c) Knowledge and skills.
- (1) The student will be able to write both common and IUPAC names for the hydrocarbon.
 - (A) Apply the IUPAC rules for writing compound names.
 - (B) Memorize the common names for the simpler compounds.
 - (C) Relate the structure of organic compounds to either IUPAC or common names.

- (2) The student will be able to relate the structure of organic molecules to atomic theory.
- (A) Relate molecular structure to bond geometry and hybridization.
 - (B) Explain the difference between conformation and configuration.
 - (C) Be able to draw both the Newman and sawhorse projections.
 - (D) Recognize the difference between empirical, molecular, and structural formulas. Be able to determine the empirical formula from the elemental analysis.
 - (E) Be able to draw all possible isomers given a molecular formula.
- (3) The student will be able to comprehend the structure, geometry, and conformation of the cyclic hydrocarbon.
- (A) Determine the geometry of the cyclic compound.
 - (B) Relate the molecular geometry to bond strain and reactivity.
 - (C) Describe and distinguish between the various conformations of cyclohexane.
 - (D) Identify the cis or the trans isomers of cyclohexane.
- (4) The student will be able to analyze and relate chemical reaction mechanisms to potential energy diagrams.
- (A) Relate potential energy diagrams to reaction mechanisms.
 - (B) Explain the difference between endothermic and exothermic reactions.
 - (C) Relate the stability of molecules and transition states to potential energy diagrams.

- (D) Relate reaction rate with activation energy.
 - (E) Describe and explain the role of a catalyst in chemical reactions.
- (5) The student will be able to write equations for the common reactions involving hydrocarbons.
- (A) Describe and be familiar with the applications of the following reactions
 - i. Wurtz reaction
 - ii. Combustion
 - iii. Halogenation
 - (B) Explain the free-radical mechanism for the halogenation of alkanes.
 - (C) Be familiar with the term “substitution reactions”.
- (6) The student will be able to describe and explain the origin and important uses of the common hydrocarbon.
- (A) Describe the source of most hydrocarbons.
 - (B) Explain the uses of the petrochemicals.
 - (C) Explain the process of crude oil refining.
 - (D) Describe some of the non-petroleum sources of carbon energy.
- (7) The student will be able to describe the properties, reactions, and uses of unsaturated hydrocarbons.
- (A) Describe the bonding involved in a multiple bond system.
 - (B) Describe the important reactions for the preparation of alkenes
 - i. Dehydration of alcohols
 - ii. Dehydrohalogenation

- (C) Explain the physical properties of the unsaturated hydrocarbon.
 - (D) Relate the mechanism of addition reactions to the various products formed.
 - (E) Describe and be able to use the application of common addition reactions of alkenes or alkynes
 - i. addition of hydrogen
 - ii. addition of halogen
 - iii. addition of water
 - iv. hydroboration
 - v. addition of hydrogen halides
 - 1. Markovnikov addition
 - 2. Anti-Markovnikov addition
 - (F) Compare and contrast addition and substitution reactions.
- (8) The student will be able to describe the characteristics of aromatic hydrocarbons and how they differ from aliphatic hydrocarbons.
- (A) Describe the history concerning the structure of the benzene molecule.
 - (B) Define aromaticity and resonance; be able to identify aromatic compounds by using the Huckel ($4n+2$) rule.
 - (C) Draw the molecular orbital representation of benzene.
 - (D) Describe and use the applications of the reactions of aromatic hydrocarbons
 - i. halogenation
 - ii. hydrogenation
 - iii. Friedal-Crafts alkylation
 - iv. nitration
 - v. sulfonation
 - (E) Name aromatic compound using both the IUPAC and common names.
 - (F) Explain the difference between ortho, para, and meta directing groups. Also be able to explain the difference between activating and deactivating groups.
 - (G) Be familiar with the more common polycyclic and heterocyclic aromatic compounds.

- (9) The student will be able to identify the different types of stereoisomers.
- (A) Describe the history of the development of optical isomerism.
 - (B) Explain and identify the difference between chiral and achiral compounds.
 - (C) Communicate the concept and calculations involved in optical rotation of plane polarized light.
 - (D) Identify optically active molecules as having either the R or S configuration.
 - (E) Be able to use the E – Z notation for geometric isomers.
 - (F) Be able to identify enantiomers, diastereomers, and meso compounds.
 - (G) Describe the process of resolving and determining the absolute configuration of enantiomers.
- (10) The student will be able to describe and identify the reactions, mechanisms, and uses of organic halide compounds.
- (A) Know both the IUPAC and common names of the organic halides.
 - (B) Describe the common methods of preparation and reactions of the organic halides.
 - (C) Explain the detailed mechanisms for these reactions (S_N1, S_N2, E1, and E2).
 - (D) Relate the stereochemistry of the S_N1 and S_N2 reactions to the mechanisms.
 - (E) Be aware of the competition between substitution and elimination reactions.
 - (F) Be able to identify methyl, primary, secondary, tertiary alkyl halides.
- (11) The student will be able to describe the importance, occurrence, and uses of alcohols and phenols.

- (A) Write IUPAC and common names for alcohols and phenols.
 - (B) Identify alcohols and being primary, secondary, or tertiary.
 - (C) Describe the role of hydrogen bonding in determining the physical characteristics of alcohols.
 - (D) Relate the acidity with the structure of the alcohol or phenol.
 - (E) Describe the common reactions for the preparation of alcohols
 - i. Grignard reaction
 - ii. hydroboration of alkenes
 - (G) Describe the common reactions of alcohols and phenols
 - i. oxidation
 - ii. conversion to alkyl halides
 - (H) Identify the names and uses of common polyols (glycols).
 - (I) Describe the structure and metabolic function of some of the biologically active alcohols (cholesterol, vitamin A and C, etc.).
- (12) The student will be able to describe the uses, preparation, and physical properties of ethers and epoxides.
- (A) Name the simpler ethers and epoxides using both common and IUPAC names.
 - (B) In terms of molecular structure, explain the low reactivity of ethers and high reactivity epoxides. Also explain the physical characteristics in these terms.
 - (C) Describe the common reactions for the preparation of ethers and epoxides
 - i. Williamson synthesis
 - ii. from peracids
 - iii. from chlorohydrins
 - (D) Describe the common reactions of ethers and epoxides
 - i. cleavage

- ii. ring opening

- (E) Explain the mechanism of the Williamson synthesis.

- (F) Describe the uses of some common ethers and crown ethers (solvents)

- (13) The student will be able to describe the names, preparation, and reactions of aldehydes and ketones.
 - (A) Name the aldehydes and ketones by the IUPAC system and common names.

 - (B) Relate the physical properties of aldehydes and ketones to their structures.

 - (C) Explain the chemical behavior of the carbonyl group.

 - (D) Describe the reactions involved in the formation of aldehydes and ketones
 - i. oxidation of alcohols
 - ii. oxidation of alkenes

 - (E) Describe the reactions of aldehydes and ketones
 - i. Reduction with lithium aluminum hydride, hydrogen, and sodium borohydride
 - ii. Oxidation of aldehydes
 - iii. Addition of Grignard reagents
 - iv. Clemmensen and Wolff-Kishner reduction

 - (F) Explain the keto and enol structures of ketones

 - (G) Describe the reason that alpha hydrogens are acidic

 - (H) For the aldol condensation
 - i. Be able to write the mechanism
 - ii. Understand the role of the alpha hydrogens
 - iii. Know the problems involved during a crossed (mixed) aldol condensation.

 - (I) Explain what is done and seen when testing for the presence of aldehydes and ketones (Fehling's, Benedict's, and Tollens tests).

- (14) The student will be able to describe the importance and uses of the carboxylic acids.
- (A) Write the IUPAC and common names for carboxylic acids.
 - (B) Relate the physical properties of carboxylic acids to the structure.
 - (C) Describe the reactions and reagents involved in the formation of carboxylic acids
 - i. Oxidation of
 - 1. primary alcohols or aldehydes
 - 2. arenes
 - ii. Arndt – Eistert synthesis
 - iii. Nitrile synthesis
 - iv. Carbonylation of Grignard reagents.
 - (D) Explain the term resonance and how it is related to the stability of the carboxyate anion.
 - (E) Relate the degree of acidity (K) to the structure of the carboxylic acid.
 - (F) Describe the common reactions of carboxylic acids.
 - i. Reduction with lithium aluminum hydride
 - ii. Conversion of acid derivatives (acid chloride, esters, anhydrides, amides)
 - iii. Alpha substitution of halides.
- (15) The student will be able to describe the characteristics and uses of esters, anhydrides, amides, and acid chlorides.
- (A) Write the IUPAC and common names of the acid derivatives
 - (B) Describe the reactions for the formation of each derivative
 - i. Anhydride – dehydration of carboxylic acids
 - ii. Esters – addition of alcohols to carboxylic acids
 - iii. Amides – addition of ammonia and ammonia derivatives to carboxylic acids.
 - (C) Explain the reactivity of acid derivatives and compared with carboxylic acids.
 - (D) Describe the reactions of the carboxylic acid derivatives
 - i. Anhydride
 - 1. hydrolysis
 - 2. Friedel-Crafts acylation
 - 3. ester formation
 - ii. Esters

1. hydrolysis
2. reduction
- iii. Amides – hydrolysis
- iv. Acid chlorides
 1. hydrolysis
 2. Friedel-Crafts acylation
 3. ester formation
 4. amide formation
 5. Rosenmun reduction.

(16) The student will be able to describe the chemical and physical characteristics of the dicarboxylic acids, hydroxyl acids, keto acids, and how they are different from the monocarboxylic acid.

- (A) Write the IUPAC and common names for the dicarboxylic acids, hydroxyl acids, keto acids.
- (B) Relate the acidity to the structure of the acid.
- (C) Describe the follow reactions
 - i. Decarboxylation
 - ii. Anhydride formation
 - iii. Lactone formation
 - iv. Claisen condensation.
- (D) Compare the structure of soaps and detergents.
- (E) Explain the biological importance and structure of fats.
- (F) Relate the melting point to unsaturation of vegetable oils.
- (G) Communicate the structure and biological function of lipids, such as steroids.

(17) The student will be able to describe the fundamental chemical and physical properties of amines, which are organic derivatives of ammonia.

- (A) Write IUPAC and common names for the amines.
- (B) Relate the degree of basicity with the structure of the amines.
- (C) Classify the amines as being primary, secondary, or tertiary.
- (D) Describe the reactions for the preparation of amines
 - i. Alkylation
 - ii. Reduction of nitro compounds
 - iii. Reduction of amides
 - iv. Reduction of nitriles
 - v. Gabriel synthesis of pure primary amines.

(E) Be familiar with some of the naturally occurring amines, such as alkaloids.

(18) The student will be able to relate the structure of a compound to its UV, NMR, IR, and mass spectrum.

- (A) Relate electromagnetic radiation to Planck's equation $E=hf$.
- (B) Discuss the location of the UV, visible, and IR regions on the electromagnetic spectrum. Also know the units used to measure wavelength and frequency.
- (C) For UV and visible spectra, discuss the
 - i. Design of the instrument used to measure absorption
 - ii. Significance of the Beer-Lambert Law
 - iii. Effect of conjugation on wavelength.
- (D) For IR spectra, discuss the
 - i. Design of the instrument
 - ii. Procedure involved in the preparation of a sample for measurement
 - iii. Determination of what functional groups are present in an organic molecule, given a chart.
- (E) For NMR spectrum, describe the
 - i. General theory of operation
 - ii. Sample preparation
 - iii. Effect of the environment on the absorption of the hydrogens
 - iv. Splitting patterns
 - v. Information obtained from the C-13 NMR.
- (F) For Mass Spectrum, describe the
 - i. Design of the instrument
 - ii. Procedure involved in determining the mass and isotope peaks
 - iii. Information obtained from the fragmentation patterns.

(19) The student will be able to discuss the structure and biological properties of drugs and natural products.

- (A) Discuss the meaning of the term "heterocyclic", for both aromatic and nonaromatic compounds.

- (B) Describe the structure and mode of action of herbicides such as 2, 4-D, paraquat, and atrazine.
 - (C) Be familiar with the structure and uses of the common alkaloids such as morphine, nicotine, curare, and atropine.
 - (D) Learn the structure of the common central nervous system drugs.
 - (E) Understand the concept of pharmacology and medicinal chemistry in terms of
 - i. Cancer drugs
 - ii. Penicillin
 - iii. Sulfa drugs
 - iv. Amphetamines
 - v. Narcotics
 - vi. Analgesic.
- (20) The student will be able to discuss the structure, chemical and physical properties of polymers, and also the mechanism of polymerization.
- (A) Name and draw the structure of some common polymers, identifying the monomer unit.
 - (B) Discuss the mechanism of polymerization.
 - (C) Differentiate between addition and condensation polymers.
 - (D) Discuss the physical and chemical characteristics of polymers.
 - (E) Explain the importance of cross-linking of polymers.
 - (F) Compare and contrast the following types of polymers; elastomer, thermoplastic and thermosetting
 - (G) Describe some of the naturally occurring polymers, such as proteins and polysaccharides

Description of the specific student needs this course is designed to meet:

The student will understand the fundamentals of organic chemistry and the data that supports these concepts. Students will learn to apply organic chemistry concepts to problem solving. Students will learn laboratory techniques in organic chemistry. Students will learn to communicate scientific data effectively through lab reports. Students will learn to work as a team member on laboratory exercises.

Major resources and materials to be used in the course:

Organic chemistry requires the use of a chemical laboratory with a working chemical hood, access to UV, IR, and mass spectroscopy, organic glassware, and the appropriate chemicals.

Required activities and sample optional activities to be used:

After studying the material presented in Organic chemistry, the student will be able to:

- Identify and carry out basic organic reactions in the laboratory
- Use various instrumentation in the laboratory such as UV and mass spectroscopy
- Apply various troubleshooting skills
- Apply the concepts gained to real life uses.

Methods for evaluating student outcomes:

The student will be evaluated upon the completion and mastering of the Essential Knowledge and Skills for Organic Chemistry as determined by the instructor.

Teacher qualifications:

The teacher for this course shall be certified in the area of Chemistry or Science Composite.

Additional information (optional):

The student will perform multiple laboratory exercises aimed at exposing them to organic chemistry techniques that are practical skills, which could be used in future research.