CHEM 0012A - ORGANIC CHEMISTRY I

Catalog Description

Prerequisite: Completion of CHEM 1B with grade of "C" or better
Advisory: Eligibility for ENGL 1A strongly recommended
Hours: 162 (54 lecture, 108 laboratory)
Description: An extensive course in the chemistry of the compounds of carbon, which emphasizes structure, kinetics, thermodynamics, spectroscopy, and synthesis. The laboratory provides direct experience with the reaction, synthesis, purification, identification, and characterization (IR, GC, TLC, bp, mp, chemical tests) of organic compounds. Discussions about the emerging field of "Green Chemistry" and performance of Green Chemistry experiments in the laboratory. Required for majors in chemistry as well as many other related fields. (C-ID CHEM 150; and, combined with CHEM 12B, C-ID CHEM 160S) (CSU, UC)

Course Student Learning Outcomes

- CSLO #1: Use experimental data to derive the structure of molecules, draw them and predict how their structure will affect their reactivity. Focus on alkanes, alcohols, ethers and alkenes.
- CSLO #2: Predict and draw mechanisms leading to products given the structure of reactant molecules. Focus on alkanes, alcohols, ethers and alkenes.
- CSLO #3: Outline a retrosynthesis and create a synthetic scheme given a target molecule. Focus on alkanes, alcohols, ethers and alkenes.

Effective Term

Fall 2022

Course Type

Credit - Degree-applicable

Contact Hours

162

Outside of Class Hours

108

Total Student Learning Hours

270

Course Objectives

Given a periodic table and other appropriate reference materials, students will be able to perform the following on examinations, laboratory exercises, or in laboratory experiments:
Lecture Objectives:
1. write a definition of an organic molecule, an organic functional group, covalent bond length, covalent bond strength, noble gas electron configuration and the periodic trend of electronegativity (Pauling);
2. compare and contrast ionic and covalent bonds;
3. relate the different bond types to electronic configurations;
4. explain the formation of chemical bonds using both molecular orbital theory and valence bond theory;
5. draw Lewis (Kekule) structures of organic molecules, calculate formal charges for atoms in the Lewis structure, determine if an atom in a Lewis structure has an octet of electrons around it, draw resonance structures (forms), draw a resonance hybrid with dotted bonds and formal charges, name the Lewis structures electron and molecular geometry, draw the molecule using wedges and dashes to represent its 3D structure, draw the molecules bond and molecular dipole moments if present and state if the molecule is polar;
6. state that the drawing of resonance structures is done as a tool and is not an actual representation of a molecules bonds changing continuously;
7. differentiate the major resonance structure(s) from the minor(s) ones for a Lewis structure;
8. define the term delocalized in terms of electrons and how this effects the energy of the electrons;
9. state the basic Quantum Mechanic descriptions of electrons;
10. state these axioms of molecular orbital theory: (a) n atomic orbitals can combine to make n bonding and antibonding molecular orbitals (M. O.'s), (b) bonding M. O.'s occur when orbitals of the same phase (+ with + or – with -) overlap and antibonding M. O.'s occur when orbitals of opposite phase overlap (+ with -), (c) antibonding M. O.'s are higher in energy than their corresponding bonding M. O.'s, (d) electrons can be described as spreading over more than two atoms in molecular orbital theory;
11. define and contrast sigma and pi covalent bonds;
12. state these axioms of hybridizations: (a) Pauling developed the theory because the geometry of molecules can not be described with the geometry of free atomic orbitals, (b) n atomic orbitals can hybridize to form n hybrid orbitals, (c) the greater the S character of the hybrid orbital the more electronegative it is;
13. draw molecule sigma and pi bonding diagrams clearly stating which orbitals overlap to form bonds and the resulting bond angles;
14. draw and read condensed molecular formulas, expanded molecular formulas (in 3D with Wedges and Dashes) and bond line molecular formulas;
15. name the following organic molecules: alkanes, cycloalkanes, alcohols, ethers, alkenes and alkynes;
16. draw cycloalkane chair conformations and determine which conformation is most stable;
17. draw Newman projects of alkanes and assess their energies;
18. draw curved arrow mechanisms;
19. draw potential energy-reaction coordinate diagrams for reactions;
20. explain how the Hammond Postulate predicts the selectivity of the different halogenations of alkanes
21. calculate degrees of unsaturation given molecular formulas;
22. define the following stereochemistry terms: isomer, constitutional isomer, stereoisomer, cis and trans isomers (alkenes and cyclohexanes), chiral, achiral, enantiomer, diastereomer, racemic mixtures, resolution of enantiomers, meso, optical rotation, specific rotation, dextrorotatory, and levorotatory;
23. assign the Cahn, Ingold, Prelog R and S absolute configurations to stereocenters;
24. state how a set of stereoisomers relate to one another;
25. define nucleophile, electrophile, leaving group and an aprotic solvent:
26. draw the curved arrow mechanism of an SN1, SN2, E1 and E2 reaction and state the factors that effects these reactions;
27. analyze the factors that effect SN1, SN2, E1 and E2 reactions and predict which reaction will predominate under particular circumstances;
28. predict the stereochemical outcomes of SN1, SN2, E1 and E2 reactions;

29. predict pKa trends for alcohols, carboxylic acids, amines, inorganic acids, alkanes, alkenes and alkynes using the concepts of induction and resonance;
30. define oxidation and reduction in terms of organic molecules;
31. draw the full oxidation/reduction series of alcohols to carboxylic acids;
32. predict missing reactants, reagents or products from the following reactions (including regio- and stereo-chemical considerations): SN1, SN2, E1, E2 NaBH4 reduction, LiAlH4 reduction, Jones oxidation, PCC oxidation, organo-lithium synthesis, Grignard synthesis, reactions of organo-lithium's and Grignards with ketones and Aldehydes and protic molecules, covert alcohols (1o, 2o, 3o) into bromides or chlorides or tosylates, Williamson ether synthesis, mineral acid ether synthesis, ether cleavage with strong acid, adding and removing protecting groups, epoxidations, acidic and basic attach of epoxides, Markovnikov and anti-Markovnikov halogenation of alkenes and alkynes, oxymercuration-demercuration hydroxylation, Markovnikov and anti-Makovnikov hydration, dihydroxylation of alkenes, ozonolysis, radical, anionic and cationic polymerizations, reduction of alkenes and alkynes, alkyne synthesis, alkyne anions synthesis and reactions, alkyne reactions with mercury(II) sulfate and dicyclohexylborane;
33. develop retrosynthetic and synthetic routs to make organic compounds from simpler components using the reactions from outcome 32. above;
34. draw curved arrow mechanism in which carbocation rearrangements (1, 2-hydride shifts and/or 1, 2-alkyl shifts) take place;
35. outline the main components of NMR, IR, MS, Polarimetry, GC and HPLC spectrometers;
36. determine the structure of unknown organic molecules given some or all of the spectra or data from the instruments listed in outcome 35. above;
37. predict the type of alkene that is produced when considering if an elimination reaction is under kinetic or thermodynamic control;
38. list and define the following "Green" chemistry principals: (a) prevention of waste is better than having to clean it up, (b) synthetic methods should strive for maximum atom economy, (c) synthetic methods should be designed to use and generate substances that possess little to no toxicity to humans and the environment, (d) chemical products should be designed to preserve efficacy of function while reducing toxicity, (e) use of auxiliary substances (solvents, separation agents, etc.) should be avoided if possible and (f) energy requirements for reactions should be minimized as much as possible.
Laboratory Objectives:
1. Write a definition of an organic molecule, an organic functional group, covalent bond length, covalent bond strength, noble gas electron configuration and the periodic trend of electronegativity (Pauling);
2. draw Lewis (Kekule) structures of organic molecules, calculate formal charges for atoms in the Lewis structure, determine if an atom in a Lewis structure has an octet of electrons around it, draw resonance structures (forms), draw a resonance hybrid with dotted bonds and formal charges, name the Lewis structures electron and molecular geometry, draw the molecule using wedges and dashes to represent its 3D structure, draw the molecules bond and molecular dipole moments if present and state if the molecule is polar;
3. name the following organic molecules: alkanes, cycloalkanes, alcohols, ethers, alkenes and alkynes;
4. draw curved arrow mechanisms;
5. calculate degrees of unsaturation given molecular formulas;
6. define the following stereochemistry terms: isomer, constitutional isomer, stereoisomer, cis and trans isomers (alkenes and cyclohexanes), chiral, achiral, enantiomer, diastereomer, racemic mixtures, resolution of enantiomers, meso, optical rotation, specific rotation, dextrorotatory, and levorotatory;
7. predict pKa trends for alcohols, carboxylic acids, amines, inorganic acids, alkanes, alkenes and alkynes using the concepts of induction and resonance;
8. outline the main components of NMR, IR, MS, Polarimetry, GC and HPLC spectrometers;
9. determine the structure of unknown organic molecules given some or all of the spectra or data from the instruments listed in outcome 35. above;
10. list and define the following "Green" chemistry principals: (a) prevention of waste is better than having to clean it up, (b) synthetic methods should strive for maximum atom economy, (c) synthetic methods should be designed to use and generate substances that possess little to no toxicity to humans and the environment, (d) chemical products should be designed to preserve efficacy of function while reducing toxicity, (e) use of auxiliary substances (solvents, separation agents, etc.) should be avoided if possible and (f) energy requirements for reactions should be minimized as much as possible;
11. Use the Nuclear Magnetic Resonance (NMR, 60 MHz) Spectrometer (Proton and Carbon spectra) by independently running multiple samples;
12. Use the Fourier Transform Infrared (FT-IR) Spectrometer (with an ATR adapter) by independently running multiple samples;
13. Obtain melting point data using melting point apparatus by independently running multiple samples;
14. Obtain Gas Chromatograph (GC) by running multiple samples in small groups.
15. Perform standard laboratory techniques such as liquid-liquid extractions, crystallizations, distillations, chromatography (column and thin layer), notebook data recording and experimental report generation (written and oral) by independently performing these tasks.

General Education Information

- Approved College Associate Degree GE Applicability
- CSU GE Applicability (Recommended-requires CSU approval)
- Cal-GETC Applicability (Recommended - Requires External Approval)
- IGETC Applicability (Recommended-requires CSU/UC approval)

Articulation Information

- CSU Transferable
- UC Transferable

Methods of Evaluation

- Problem Solving Examinations
  - Example: Draw the structure of (Z)-2-Fluoro-4,4-dimethyl-2-pentene.
- Reports
  - Example: Write a formal report (using the format of the Journal of Organic Chemistry) for the synthesis of isopentyl acetate (Banana Oil).
- Skill Demonstrations
  - Example: Draw the (a) major product and (b) curved arrow mechanism for the major product, of the reaction between 2-Methyl-2-butene and dilute phosphoric acid.

Repeatable

No

Methods of Instruction

- Laboratory
- Lecture/Discussion
- Distance Learning

Lab:

1. Instructor will assign students to read and outline the experiment in the laboratory material on distillation. In class the instructor will introduce the experiment and direct students to begin the experiment under their supervision. Online the Instructor will provide text and video from which the students will extract data. Instructor will provide assistance as necessary for individual students as they work through the experiment.

Lecture:

1. After lecturing on the reaction between Grignard reagents and ketones three types of problems are presented to the student to work on. The problems are; (a) draw the curved arrow mechanism of the reaction between phenyl magnesium bromide and ethanal (with an acidic work-up), (b) provide the products of the reaction between Ethyl magnesium bromide and acetone, water and benzaldehyde and (c) draw the Retrosynthesis and Synthesis of the a racemic mixture of 2-butanol from two carbon or less starting organic compounds. As the students work on the problem, the instructor will walk around providing assistance. If the course is online the lecture material will be presented with videos and a slide lecture presentation. Problem solving will take place on a shared interactive white board via a Google Jamboard. The instructor will interact and assist in the problem-solving process on the shared whiteboard as students solve the problem.

Distance Learning

1. After lecturing on the reaction between Grignard reagents and ketones three types of problems are presented to the student to work on. The problems are; (a) draw the curved arrow mechanism of the reaction between phenyl magnesium bromide and ethanal (with an acidic work-up), (b) provide the products of the reaction between Ethyl magnesium bromide and acetone, water and benzaldehyde and (c) draw the Retrosynthesis and Synthesis of the a racemic mixture of 2-butanol from two carbon or less starting organic compounds. As the students work on the problem, the instructor will walk around providing assistance. If the course is online the lecture material will be presented with videos and a slide lecture presentation. Problem solving will take place on a shared interactive white board via a Google Jamboard. The instructor will interact and assist in the problem-solving process on the shared whiteboard as students solve the problem.

Typical Out of Class Assignments

Reading Assignments

1. Read and "Pre-lab" the experiment in which Gas Chromatography Mass Spectroscopy is used to analyze gasoline samples, known organic molecules and unknowns organic molecules. A "Pre-Lab" includes reading theory about the instrument and answering question about this theory. 2. Read the chapter on cycloalkanes and answer the in-text questions.

Writing, Problem Solving or Performance

1. Write up a report on the results from the Gas Chromatography of gasoline experiment. The report will include the determination of a pair of unknown molecules identities and the volume ratio between them. 2. Write up a formal report for the synthesis of aspirin experiment. This report will include (a) title, (b) author name, (c) abstract, (d) keywords, (e) introduction, (f) results, (g) discussion, (h) conclusion, (i) acknowledgements, (j) experimentals and (k) references in the format of the Journal of Organic Chemistry. 3. Give an oral presentation on the determination of an unknown organic molecules using extraction, purification and characterization techniques (NMR and IR).

Other (Term projects, research papers, portfolios, etc.)

Required Materials

- A Microscale Approach to Organic Laboratory Techniques
  - Author: Donald L. Pavia, et al
  - Publisher: Engage
  - Publication Date: 2018
  - Text Edition: 6th
  - Classic Textbook?:
  - OER Link:
  - OER:
- Organic Chemistry: Structure and Function
  - Author: K. Peter C. Vollhardt and Neil E. Schore
  - Publisher: W. H. Freeman and Co.
  - Publication Date: 2018
  - Text Edition: 8th
  - Classic Textbook?:
  - OER Link:
  - OER:

Other materials and-or supplies required of students that contribute to the cost of the course.

Safety goggles