CHEM 12C: ORGANIC CHEMISTRY

Foothill College Course Outline of Record

Heading	Value
Effective Term:	Summer 2021
Units:	4
Hours:	4 lecture per week (48 total per quarter)
Prerequisite:	CHEM 12B and CHEM 12BL or 13BH.
Advisory:	Concurrent enrollment in CHEM 12CL or 13CH recommended, as CHEM 12CL is major transfer requirement - please consult a counselor.
Degree & Credit Status:	Degree-Applicable Credit Course
Foothill GE:	Non-GE
Transferable:	CSU/UC
Grade Type:	Letter Grade (Request for Pass/No Pass)
Repeatability:	Not Repeatable

Student Learning Outcomes

- Apply theoretical models that incorporate the structure-reactivity relationships of organic compounds to solving problems and rationalizing observations.
- Design multi-step syntheses of organic target molecules from simple precursors by applying a comprehensive understanding of functional group transformations.
- Predict the structure and reactivity of aldehydes, ketones, amines, carboxylic acids, acid chlorides, anhydrides, esters, amides, nitriles, enolates, and bioactive molecules including carbohydrates, amino acids and peptides.
- Propose the mechanism of a chemical transformation using curved-arrow formalism that is consistent with known kinetic data.

Description

The third and final quarter of organic chemistry expands the study of functional groups to include ketones, aldehydes, carboxylic acids and its derivatives, and amines. Also introduces the chemistry of polyfunctional, biologically active molecules such as proteins and carbohydrates. Continued emphasis on structure-reactivity relationships, mechanisms of reaction and multi-step syntheses. For chemistry and other STEM majors as well as any pre-professional students studying for careers in dentistry, medicine, pharmacy, veterinary medicine and for any other interested students who have mastered the prerequisites.

Course Objectives

The student will be able to:
A. Expand knowledge of functional group chemistry to include ketones and aldehydes, carboxylic acids and their derivatives, and amines.
B. Apply knowledge of functional groups to understand the chemistry of bioactive molecules including carbohydrates and proteins.
C. Apply theoretical models that address the structure-reactivity relationships of organic compounds.
D. Design the multi-step synthesis of an expanded array of target organic molecules from simple precursors using strategies that incorporate both regio- and stereoselectivity, and chemoselectivity in polyfunctional compounds.
E. Devise the structure of an organic compound from a combination of chemical and/or spectroscopic information.
F. Communicate effectively using the language of organic chemistry.
G. Work constructively and collaboratively in groups.

Course Content

A. Expand knowledge of functional group chemistry to include ketones and aldehydes, carboxylic acids and their derivatives, and amines
1. Ketones and aldehydes
a. Physical properties
b. Formation
1) Oxidation of alcohols
2) Hydration of alkynes via hydroboration-oxidation or oxymercuration
3) Ozonolysis of an alkene
c. Reactivity of ketones and aldehydes
1) Reversible reaction with water or alcohols
2) Reaction with amines to form imines or enamines
3) Reaction with cyanide or acetylide anions
4) Reaction with phosphorus ylides: the Wittig reaction
5) Reaction with Grignard reagents and organolithium reagents
6) Reduction with sodium borohydride or lithium aluminum hydride
7) Acidity and formation of enolates
8) Reaction at α-carbon
a) Reaction with LDA under kinetic vs. thermodynamic control
b) α-alkylation
c) α-halogenation under basic and acidic conditions
d) The haloform reaction
e) The aldol reaction
f) β-diketones: formation via Michael addition
g) Robinson annulation
2. Carboxylic acids
a. Physical properties
b. Relative acidity of substituted carboxylic acids
c. Preparation
1) Via oxidation of alcohols or aldehydes
2) Via oxidation of benzylic carbon
3) Via hydrolysis of nitriles
4) Via Grignard reaction with alkyl, vinyl or aryl halides and CO_2
d. Reactivity
1) With thionyl chloride and phosphorous tribromide to form acid halides
2) With carboxylic acid chlorides to form anhydrides
3) With alcohols and catalytic mineral acids to form esters
4) With amines to form amides
5) With $LiAlH_4$ to form alcohols
6) With molecular bromine and PBr_3 to form alpha-brominated acids
3. Carboxylic acid derivatives
a. Relative reactivity of acid chlorides, anhydrides, esters, carboxylic acids, and amides: correlation to leaving group ability
b. Interconversion of derivatives via addition-elimination mechanism
c. Acid chlorides
1) Reduction of acid chlorides with lithium tri(tert-butoxy)aluminum hydride to form aldehydes
2) Reaction of acid chlorides with organocuprates to form ketones
3) Interconversion to anhydrides, esters, carboxylic acids and amides via addition-elimination mechanism

d. Esters
1) Reduction with $LiAlH_4$ and DIBAL
2) Reaction with Grignard reagents
3) Reaction at α-carbon
a) Claisen condensation
b) Decarboxylation of β-ketoacids
c) Variation: ketone nucleophile + ester electrophile
d) Intramolecular: Dieckmann reaction
e) Biochemical versions of Claisen: Acetyl-CoA conversion to isopentylpyrophosphate (terpene) (time permitting)
e. Beta-ketoesters
1) Alkylation
2) Malonic ester synthesis
3) Acetoacetic ester synthesis of methyl ketones
f. Amides
1) Hofmann rearrangement of amides with halogens in aqueous base
2) Reduction with $LiAlH_4$ and DIBALH
3) Hydrolysis with acid or base catalyst
g. Nitriles
1) Hydrolysis to amides and carboxylic acids
2) Reaction with Grignard reagents to form ketones
3) Reaction with $LiAlH_4$ and DIBAL to form amines and aldehydes, respectively
4. Conversion of electrophilic acyl derivatives to nucleophilic acyl anions
a. Via 1,3-Dithioalkanes (time permitting)
b. Via catalysis with thiazolium salts
5. Amines
a. Properties
b. Preparation
1) From other amines via nucleophilic substitution
2) From nitriles, amides and azides via reduction
3) Gabriel synthesis
4) From aldehydes and ketones via reductive amination
c. Reactivity
1) Hofmann elimination
2) Mannich reaction
3) Nitrosation of amines and diazonium ions
6. Substituted benzene (elements not covered in prerequisite course)
a. Reactivity of benzylic carbon
1) Oxidation
2) Substitution
3) Acidity
b. Reactions of aryldiazonium ions
1) With water
2) The Sandmeyer reaction: Reaction with Cu(I) salts
3) Reduction with H_3PO_2
c. Reactivity of phenols
1) Electrophilic substitution
2) Claisen rearrangement (time permitting)
3) Oxidation to quinones (time permitting)
B. Apply knowledge of functional groups to understand the chemistry of bioactive molecules including carbohydrates and proteins
1. Carbohydrates
a. Monosaccharides
1) Fischer projections and D,L-nomenclature
2) Cyclic forms and mutarotation
3) Optical activity and structure determination
4) Reactivity
a) Reducing sugars: reaction with Fehling's and Tollen's solutions
b) Oxidative cleavage with periodic acid
c) Condensation with amine derivatives
d) Esterification and alkylation of hydroxy-groups
e) Formation of glycosides
f) Glycosides and mutarotation
g) Sugar chain extension by cyanohydrin formation and reduction
h) Sugar chain shortening by Ruff degradation
b. Disaccharides: formation and hydrolysis
2. Amino acids and peptides
a. Structure
b. Acid/base properties
c. Synthesis of amino acids
1) SN2 reaction of ammonia with α-haloacid
2) Diethyl acetamidomalonate alkylation, hydrolysis and decarboxylation
3) The Strecker synthesis
d. Peptides: primary structure
1) The peptide bond
2) Sequencing
3) Cleavage
a) With aqueous acid at every peptide bond
b) With cyanogen bromide BrCN at methionine C terminus
c) With chymotrypsin at Phe, Tyr, Trp
d) With trypsin at Lys, Arg
e) Using Edman degradation
f) Using Sanger's reagent to identify N-terminus
g) Separation and identification of amino acid fragments via gel electrophoresis, ion-exchange chromatography, and mass spectrometry
4) Peptide synthesis
a) Traditional solution synthesis
b) Merrifield solid phase synthesis
C. Apply theoretical models that address the structure-reactivity relationships of organic compounds
1. Kinetic vs. thermodynamic control in enolate formation and α,β-unsaturated ketone addition
2. Relative reactivity of carboxylic acid derivatives and transition state theory
3. Proposing mechanism of unknown reaction by analogy to defined systems
4. Assessing conformation-dependent structural features to predict reactivity
D. Design the multi-step synthesis of an expanded array of target organic molecules from simple precursors using strategies that incorporate both regio- and stereoselectivity, and chemoselectivity in polyfunctional compounds
1. Polysubstituted aromatics
2. Amino acids and dipeptides
3. Selective reactions of β-dicarbonyl derivatives
4. Comprehensive functional group transformations: interconversion of all functional group categories discussed throughout the 12ABC sequence
E. Devise the structure of an organic compound from a combination of chemical and/or spectroscopic information
1. Given MS, IR and 1H NMR data, deduce the structure of an organic unknown
2. Given knowledge of chemical reactivity, predict features of an IR spectrum
F. Communicate effectively using the language of organic chemistry
1. Explain the rationale behind a chemical trend both verbally and in writing
2. Correlate chemical structures with their nomenclature
G. Work constructively and collaboratively in groups

Lab Content

Not applicable.

Special Facilities and/or Equipment

None.

Method(s) of Evaluation

Quizzes
Written short answer examinations
Final cumulative examination: short answer and multiple choice

Method(s) of Instruction

Lecture
Discussion
Group work

Representative Text(s) and Other Materials

Klein, D.. Organic Chemistry, 3rd ed.. 2017.

Wade, L.G.. Organic Chemistry, 9th ed.. 2016.

Smith, Janice. Organic Chemistry, 5th ed.. 2016.

Solomons, T.W. Graham. Organic Chemistry, 12th ed.. 2017.

Types and/or Examples of Required Reading, Writing, and Outside of Class Assignments

A. Weekly reading assignments from the textbook discussing the principles that govern organic reactions (e.g., electron flow, structure/reactivity relationship, etc.).
B. Homework problems that require written explanations of chemical behavior based on application of known theoretical models.

Discipline(s)

Chemistry