DeAnza College

Program Applicable
Effective Quarter: Fall 2016

I. Catalog Information

CHEM 12C **Organic Chemistry** **5 Unit(s)**

Prerequisite: CHEM 12B with a grade of C or better.

Advisory: EWRT 1A or EWRT 1AH or (EWRT 1AS and EWRT 1AT) or ESL 5.

Graded

Lec Hrs: 36.00
Lab Hrs: 72.00
Out of Class Hrs: 72.00
Total Student Learning Hrs: 180.00

An exploration of the physical properties and chemical behavior of important classes of organic compounds, focusing on amines, carboxylic acids, and carboxylic acid derivatives, with an introduction to the chemistry of terpenes, lipids, carbohydrates, and proteins. Emphasis on retrosynthesis, spectroscopic structure determination, and reaction mechanism. Laboratory experiments involving the multi-step synthesis of organic compounds and the characterization of those compounds using chromatography and infrared (IR) and nuclear magnetic resonance (NMR) spectroscopy. For chemistry majors or those in closely allied fields such as biochemistry and chemical engineering.

Course Justification: This course is a major preparation requirement in the discipline of chemistry at all CSUs and UCs. This course belongs on the Biological Sciences Associates in Sciences degree. This is the third of three courses in the Organic Chemistry sequence of classes where students are introduced to topics in biological-organic chemistry.

• **Student Learning Outcome**: Apply the principles of thermodynamics, kinetics, equilibrium to biologically important molecules.

• **Student Learning Outcome**: Conduct sectroscopic analysis and identifiy structures of biologically important molecules.

• **Student Learning Outcome**: Generate stepwise reaction mechanisms of biologically important molecules.

• **Student Learning Outcome**: Design logical syntheses and structural modifications of biologically important molecules.

II. Course Objectives

A. Compose valid names for amines, carboxylic acids and derivatives, carbohydrates, and proteins using both common and IUPAC nomenclature conventions.

B. Investigate the role of stereochemistry in the reactivity of biological molecules.

C. Predict the reactivity of amines, carboxylic acids and derivatives, carbohydrates, and proteins on the basis of their structure.

D. Create detailed reaction mechanisms and use those mechanisms to explain experimental observations or predict the likely outcome of reactions of amines, carboxylic acids and derivatives, carbohydrates, and proteins.

E. Survey the fundamental reactions of biologically-active organic molecules.

F. Construct detailed synthetic schemes for the interconversion of amines, carboxylic acids and derivatives, carbohydrates, and proteins by functional group transformation using retrosynthetic analysis.

G. Examine the behavior of amines, carboxylic acids and derivatives, carbohydrates, and proteins by utilizing the frameworks of kinetics, thermodynamics, and equilibrium.

III. Essential Student Materials

None

IV. Essential College Facilities

Fully equipped chemical laboratory including, at a minimum, the following: consumable chemicals, chemical balances, glassware, molecular models, melting point apparatus, laptops with data acquisition modules, fume hoods, chemical disposal facilities, lockable student storage areas, and laboratory technician.

V. Expanded Description: Content and Form

A. Compose valid names for amines, carboxylic acids and derivatives, carbohydrates, and proteins using both common and IUPAC nomenclature conventions.

1. Examine the guidelines for naming organic compounds based on current IUPAC committee recommendations.

a. Amines

b. Carboxylic acids

c. Acyl halides, anhydrides, esters, amides, lactones, lactams, imides, and nitriles

2. Survey key examples of traditional or common nomenclature.

a. Common names of carboxylic acids and carboxylic acid derivatives

b. Nomenclature and classification of carbohydrates and carbohydrate derivatives

1. D/L convention of carbohydrates

2. Functional group - aldose, ketose

3. Carbon chain length - triose, tetrose, pentose, hexose

4. Ring sizes - furanose and pyranose

5. Anomer configuration - alpha and beta

6. Names of common aldoses and ketoses

7. Disaccharides - maltose, sucrose, and lactose

c. Common names of amino acids and peptide chains

1. D/L convention of amino acids
2. The twenty (plus) common amino acids
3. Peptide chain sequence representation

B. Investigate the role of stereochemistry in the reactivity of biological molecules.

1. Examine the stereochemistry of carbohydrates
   - **a.** Representation of cyclic carbohydrates
     1. Fischer projections
     2. Haworth projections
   - **b.** Mutarotation
   - **c.** The anomer effect
   - **d.** The Fischer glucose stereochemistry proof
   - **e.** Metabolism of D versus L forms of carbohydrates
2. Examine the role of peptide structure in biological processes
   - **a.** Metabolism of L versus D forms of amino acids
   - **b.** Primary, secondary, tertiary, and quaternary protein structure

C. Predict the reactivity of amines, carboxylic acids and derivatives, carbohydrates, and proteins on the basis of their structure.

1. Examine the relative reactivity of carboxylic acids and carboxylic acid derivates.
   - **a.** Inductive effects of substituents at the carbonyl position
   - **b.** Effect of resonance stabilization of conjugate base
2. Investigate the role of delocalization in the formation of enols and enolates.
3. Predict the acid dissociation constants of carbonyl-containing compounds.
   - **a.** Resonance stabilization of anions
   - **b.** Inductive effects of substituents
4. Estimate the basicity of amines.
   - **a.** Resonance stabilization of heterocycles such as pyrrole
   - **b.** Hybridization effects in molecules such as pyridine
   - **c.** Inductive effects of alkyl substitutents
5. Examine the acid/base characteristics of amino acids
   - **a.** Amphoterism
   - **b.** Zwitterionic structure
   - **c.** The isoelectronic (pI) point

D. Create detailed reaction mechanisms and use those mechanisms to explain experimental observations or predict the likely outcome of reactions of amines, carboxylic acids and derivatives, carbohydrates, and proteins.

1. Examine the effects of delocalization on the reaction of carbonyl compounds.
    a. Acid-catalyzed versus base-promoted formation of enol intermediates
    b. Acid-catalyzed versus base-promoted bromination of carbonyl compounds
    c. The malonic and acetoacetic ester syntheses
    d. Alkylation of ketones, esters, and nitriles
    e. Carbonyl condensation reactions
        1. Pure, mixed, and intramolecular Aldol condensations
        2. Pure, mixed, and intramolecular (Dieckmann) Claisen condensations
        3. Michael additions
        4. Stork enamine reaction
        5. Robinson annulation
2. Survey the major reactions of amines.
    a. Synthesis of amines
        1. Gabriel amine synthesis
        2. Reductive amination
        3. Hofmann rearrangement of amides
        4. Curtius rearrangement of acyl azides
    b. Reactions of amines
        1. Hofmann elimination reaction
        2. Activating effects of amines in aromatic compounds
        3. The Sandmeyer reaction
        4. Diazonium coupling
3. Explore the major reactions of carboxylic acids and carboxylic acid derivatives.
    a. Cationic versus anionic additions
    b. Carboxylic acids
        1. Synthesis of carboxylic acids - oxidation and carboxylation
        2. Conversion to acyl halides
        3. Dehydration to anhydrides
        4. Reduction
        5. Esterification - Fischer esterification, diazomethane
        6. Amidization - Acyl halides, DCC
        7. Decarboxylation - Carbonic acid, carbamic acids, carbamates, urea, beta-ketoacids
    c. Acyl halids and anhydrides

1. Solvolysis
2. Reduction to alcohols
3. Selective reduction of acyl halides to aldehydes
4. Alkylation - Grignards, dialkylcuprates

d. Esters

1. Solvolysis and saponification
2. Reduction to alcohols
3. Selective reduction to aldehydes
4. Alkylation

e. Amides

1. Dehydration to nitriles
2. Solvolysis and saponification
3. Reduction

f. Nitriles

1. Solvolysis
2. Reduction
3. Alkylation
4. Hydrogenation

E. Survey the fundamental reactions of biologically-active organic molecules.

1. Investigate the reactions of carbohydrates and carbohydrate derivatives.

a. Cyclization and decyclization of carbohydrates

b. Glycoside formation

c. Reduction of carbohydrates to alditols

d. Oxidation of carbohydrates to aldonic and aldaric acids

e. Reducing sugars and the Tollens' test

f. The Kiliani-Fischer chain extension synthesis

g. The Wohl Degradation

2. Examine the reactions of amino acids and peptide chains.

a. Synthesis of amino acids

b. Methods for synthesizing peptide chains, such as the use of the polymer-supported dicyclohexylcarbodiimide (DCC) coupling of tert-butoxycarbonyl-protected amino acids.

c. Assay of peptide chains using ninhydrin-assisted titration

d. The Edman degradation of peptide chains

e. Structure and sequencing of proteins

3. Differentiate between major classes of lipids
   a. Phospholipids
   b. Terpenoids
   c. Steroids
4. Optional topics: DNA; catabolism of fat; glycolysis; the Krebs cycle

F. Construct detailed synthetic schemes for the interconversion of amines, carboxylic acids and derivatives, carbohydrates, and proteins by functional group transformation using retrosynthetic analysis.
   1. Compare the interconversion of various carboxylic acid derivatives, such as esters, amides, acyl halides, and anhydrides.
   2. Investigate the degradation and extension of carbohydrate and protein chains.

G. Examine the behavior of amines, carboxylic acids and derivatives, carbohydrates, and proteins by utilizing the frameworks of kinetics, thermodynamics, and equilibrium.
   1. Investigate the reversibility of reactions involving carbonyl-containing compounds
      a. Reversibility of cationic mechanisms such as acid-catalyzed esterification
      b. Irreversibility of anionic reactions such as saponification on the basis of the acidity of the reactant(s) versus product(s).
   2. Examine the effects of tautomerization on the reactivity of carbonyl compounds
      a. Relativity stability of tautomer forms
      b. Reversibility of reactions with enolate intermediates
      c. Forced enolate formation using bases such as lithium diisopropylamide

VI. Assignments

A. Required readings from the textbook and laboratory manual

B. Discretionary written problems from each lecture chapter and laboratory experiment

C. Written laboratory reports for each experiment performed in the laboratory

VII. Methods of Instruction

0. Lecture and visual aids
   Laboratory demonstrations
   Discussion of assigned readings
   Discussion of problem solving performed in class
   Quiz and examination review performed in class
   Homework assignments
   Collaborative learning and small group exercises
   Laboratory experience which involves students in formal exercises of data collection and analysis
   Laboratory discussion sessions and quizzes that evaluate the experiments performed

VIII. Methods of Evaluating Objectives

A. At least three one-hour written examinations designed to periodically assess the students' ability to apply concepts and skills acquired through one of more modes of instruction, such as lecture,

assigned readings, small group discussions, or homework problems.

B. At least one written laboratory examination designed to assess the students' ability to apply concepts and skills acquired through conducting laboratory experiments and preparing written laboratory reports.

C. Regular homework assignments and/or lecture quizzes designed to periodically assess the students' progress in acquiring key concepts and skills.

D. Laboratory reports for each experiment performed, which will be used to assess the ability of a student to clearly and logically express the qualitative or quantitative results of an experiment. Laboratory reports will include an analysis of any relevant spectral or physical data and, optionally, a discussion of theoretical or experimental concepts applied in the experiment.

E. Comprehensive final lecture exam designed to assess the students' ability to critically apply concepts and skills introduced throughout the course.

F. One-hour in-class final lab examination designed to assess the students' ability to apply concepts and skills acquired through conducting laboratory experiments and preparing written laboratory reports.

IX. Texts and Supporting References

A. Examples of Primary Texts and References

1. *Klein, David. "Organic Chemistry", 2e. Wiley, 2015.
2. *Gilbert, John C. and Martin, Stephen F. "Experimental Organic Chemistry: A Miniscale and Microscale Approach", 6e. Brooks/Cole, 2015.

B. Examples of Supporting Texts and References

1. Smith, Janice G. "Study Guide/Solutions Manual for Organic Chemistry", 4e. McGraw-Hill, 2014.

X. Lab Topics

A. Laboratory methodology

1. Maintaining a laboratory notebook
2. Writing laboratory reports

B. Chemical safety

1. Materials safety data sheets (MSDS)
2. Chemical disposal
   - **a.** Separation of waste streams
   - **b.** Proper disposal methods
   - **c.** Environmental hazards of improper waste disposal
3. Laboratory environment
   - **a.** Maintaining laboratory cleanliness
   - **b.** Chemical labeling
   - **c.** Segregation of chemicals by hazard
   - **d.** Secondary containment

4. Personal safety
    a. Safety goggles
    b. Limiting chemical exposure
    c. Safety showers
    d. Eyewash stations
    e. Proper use of fire extinguishers
5. Emergency situations
    a. Fires
    b. Earthquakes
    c. Evacuation procedures

C. Analyze spectroscopic data to determine the structure of organic compounds.

1. Review the central concepts of spectroscopy.
2. Analyze organic compounds using infrared (IR) spectrophotometry.
    a. Effects of dimerzation in carboxylic acids
    b. Interpretation of IR spectra
3. Elucidate the structure of organic compounds using nuclear magnetic resonance spectroscopy (NMR).

D. Laboratory experiments

1. Synthesis of an ester such as isopentyl acetate (banana oil)
2. Aldol condensation such as the reaction of benzaldehyde with acetophenone
3. Preparation of an unsaturated ketone via Robinson annulation
4. Synthesis of an amide such as benzocaine or N,N-diethyl-m-toluamide
5. Synthesis and observation of luminol
6. Preparation of an organic compound, such as a dipeptide, via multi-step synthesis
7. Identification of an unknown compound using qualitative and spectroscopic methods (optional)