



# ILLINOIS VALLEY COMMUNITY COLLEGE

## COURSE OUTLINE

**DIVISION: Natural Sciences & Business**

**COURSE: CHM 2002 Organic Chemistry**

Date: Spring 2023

Credit Hours: 5

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

Prerequisite(s): CHM 1007

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:	<input checked="" type="checkbox"/> <b>Lecture</b>	<b>3 Contact Hours</b> (1 contact = 1 credit hour)
	<input checked="" type="checkbox"/> <b>Seminar</b>	<b>1 Contact Hours</b> (1 contact = 1 credit hour)
	<input checked="" type="checkbox"/> <b>Lab</b>	<b>3 Contact Hours</b> (2-3 contact = 1 credit hour)
	<input type="checkbox"/> <b>Clinical</b>	<b>0 Contact Hours</b> (3 contact = 1 credit hour)

Offered:  **Fall**    **Spring**    **Summer**

**CATALOG DESCRIPTION and IAI NUMBER (if applicable):**

The course covers the fundamental principles of organic chemistry stressing the preparation, reactions, mechanisms and structure of organic compounds. Laboratory includes basic techniques in compound purification, synthesis and identification. Hands-on application of FT-Infrared spectroscopy and gas chromatography are utilized in qualitative and quantitative analysis of organic compounds. **IAI Equivalent: CHM 913**

## ACCREDITATION STATEMENTS AND COURSE NOTES:

None

## COURSE TOPICS AND CONTENT REQUIREMENTS:

1. Review of general chemistry
  - a. Electrons, bonds, Lewis structures
  - b. Molecular structure
  - c. Dipole moments
  - d. Intermolecular forces
2. Molecular representations
  - a. Bond-line structures
  - b. Formal charges, lone pairs
  - c. Three-dimensional bond-line structures
  - d. Resonance, curved arrows, localized/delocalized lone pairs
3. Acids and bases
  - a. Quantitative
  - b. Qualitative
  - c. Leveling, solvation
4. Alkanes
  - a. Nomenclature
  - b. Constitutional isomers
  - c. Relative stabilities
  - d. Newman projections, conformational analysis
5. Cycloalkanes
  - a. Conformational analysis, chair vs. boat
  - b. Substituted cyclohexane, *cis-trans* isomerism
6. Stereoisomerism
  - a. Cahn-Ingold-Prelog system
  - b. Optical activity
  - c. Enantiomers, diastereomers
  - d. Symmetry and chirality
  - e. Fischer projections
7. Reactivity and mechanisms
  - a. Enthalpy, entropy, Gibbs Free Energy
  - b. Equilibria, kinetics, energy diagrams
  - c. Nucleophiles and electrophiles
  - d. Mechanisms: arrow pushing
  - e. Carbocation rearrangements
8. Substitution reactions
  - a.  $S_N1$  and  $S_N2$  reactions
  - b. Determining the dominant reaction
9. Alkenes
  - a. Nomenclature
  - b. Stereoisomerism
  - c. Stability
  - d. E1 and E2 reactions

- e. Substitution versus elimination
  - f. Addition reactions
  - g. Synthesis strategies
10. Alkynes
    - a. Nomenclature
    - b. Preparation of alkynes
    - c. Reactions of alkynes
    - d. Synthesis strategies
  11. Radical reactions
    - a. Selectivity
    - b. Stereochemistry
  12. Synthesis
  13. Alcohols and phenols
    - a. Nomenclature
    - b. Acidity
    - c. Preparation of alcohols
    - d. Reactions of alcohols

#### **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:**

Textbook: *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 demonstrate prior understanding of chemical concepts and be able to apply them to organic chemistry principles. Determine Lewis structures, predict acidity orders of compounds based on structure and periodic properties, draw Newman projections of specific carbon-carbon bond conformations and relate these to potential energy diagrams.

Competency 1.1 Students will be able to predict from rules for Lewis Structures if one isomeric structure would be expected to be more stable than another.

Competency 1.2 Students will be able to write all equivalent resonance structures if any exist.

Competency 1.3 Students will be able to predict, giving rationale, which of two non-equivalent resonance structures would be more stable.

Competency 1.4 Students will be able to predict the shape or bond angles for simple molecules using knowledge of electronic hybridization theory.

Competency 1.5 Students will be able to state properties and structures which cause compounds to be acidic.

Competency 1.6 Students will be able to list types of organic compounds which are more acidic or less acidic based on their structure.

Competency 1.7 Students will be able to draw the Newman projection for the rotation about a specific carbon-carbon bond, showing both eclipsed and staggered conformations when given the structure of the alkane or cycloalkane.

Competency 1.8 Students will be able to relate these conformations to the potential energy diagram for the rotation about the carbon-carbon bond.

Competency 1.9 Students will be able to state how the stability of the cycloalkanes is related to the ring size in terms of angle strain and conformational interactions.

Competency 1.10 Students will be able to construct a perspective drawing of the chair conformation of cyclohexane which will indicate the axial and equatorial groups.

Competency 1.11 Students will be able to use conformational analysis of the different chair conformations of cyclohexane to determine relative stability of substituted cyclohexane.

**Outcome 2** - Students will be able to demonstrate an understanding of IUPAC nomenclature for compounds containing the following functional groups: alkane, alkene, alkyne, alcohol, Alkyl Halide, and combinations thereof.

Competency 2.1 Students will be able to give the common name for any of the simple organic functional groups in the table of the text.

Competency 2.2 Students will be able to give the correct IUPAC name for any simple hydrocarbon or oxygen-derivative of a hydrocarbon; or given the name, give the structure.

Competency 2.3 Students will be able to state the common names of the isomeric hydrocarbon groups containing two, three or four carbons.

Competency 2.4 Students will be able to work out the isomeric structures of hydrocarbons containing up to seven carbons.

Competency 2.5 Students will be able to give the name for an alkene if given its structure, and to draw its structure if given the name using cis/trans as well as E/Z notation as appropriate.

Competency 2.6 Students will be able to give the name for an alkyne if given its structure, or to draw its structure given its name.

Competency 2.7 Students will be able to name alcohols given the structure, or to draw the structure when given the name.

**Outcome 3** - demonstrate an understanding of the 3-dimensional nature of organic molecules and how those molecules behave in 3-dimensional space (relate Fisher projections to chiral molecules, and, given chiral molecules, draw a correct Fisher projection).

Competency 3.1 Students given a model of a compound with one chiral center will be able to draw a correct Fisher projection and assign its (R-S) configuration.

Competency 3.2 Students given a model or formula of a compound with two chiral centers will be able to draw a correct Fisher projection and assign the R/S configuration for both centers.

Competency 3.3 Students will be able to determine whether a molecule could have optical activity, draw Fisher projections for all stereoisomers of the molecule correctly labeling them as enantiomers, diastereomers, or meso compounds.

Competency 3.4 Students will be able to construct a model of a compound given its Fisher projection.

Competency 3.5 Students will be able to explain the geometry of free radicals.

**Outcome 4** - Students will be able to demonstrate an understanding of the various mechanistic pathways that organic chemicals use to react: SN1, SN2, E1, E2, and free radical chain reaction mechanisms.

Competency 4.1 Students will be able to describe the SN1, SN2, E1 and E2 mechanisms.

Competency 4.2 Students will be able to draw a reaction profile diagram given thermodynamic data or the relative order of rate constants for a simple reaction.

Competency 4.3 Students will be able to interpret a reaction profile diagram in terms of relative rates and equilibria, and identify reactants, products, transition states, intermediates, and activation energy.

Competency 4.4 Students will be able to explain and/or predict the effect of changing any one of the following items on the mechanistic pathway (SN1, SN2, E1, E2):

- A. Basicity or nucleophilicity of the attacking reagent
- B. Substrate structure
- C. Leaving group
- D. Solvents

Competency 4.5 Students will be able to write the steps in a free radical chain reaction mechanism for halogenation of alkanes.

Competency 4.6 Students will be able to predict the products of monochlorination or monobromination of an alkane and the expected approximate percentages of each product using the relative reactivities of C-H bonds toward chlorine or bromine.

Competency 4.7 Students will be able to explain the anti-Markovnikov addition of HBr to free radicals and give the mechanism.

Competency 4.8 Students will be able to explain how the ozone layer can be destroyed by free radical reactions and give the steps of the mechanism by which this might occur.

Competency 4.9 Students will be able to give the mechanisms for dehydrohalogenation and dehydration reactions.

**Outcome 5** - Students will be able to demonstrate an understanding of organic chemical reactions and synthesize a compound using multiple organic chemical reactions including but not limited to synthesis of and basic reactions of alcohols, alkenes, alkynes, and alkyl halides.

Competency 5.1 Students will be able to predict the relative stability of alkenes given their structure.

Competency 5.2 Students will be able to recognize in a mechanism the transition state and intermediates, what bonds are being broken or formed, any conformational preference of the transition state.

Competency 5.3 Students will be able to give or complete the equations for the following reactions of alkenes along with any stereochemical preferences, i.e., Markovnikov or anti-Markovnikov orientation, syn- or anti- addition.

A. Hydrogenation

B. Addition of HX (ionic); addition of HBr (radical)

C. Addition of halogens X<sub>2</sub>

D. Addition of H<sub>2</sub>O

1. By mercuric acetate and reduction (oxymercuration-demercuration)

2. By hydroboration and oxidation

E. Oxidation by KMnO<sub>4</sub>, ozone, or peroxyacids

Competency 5.4 Students will be able to compare and explain the acidity of terminal alkynes with water, alcohol, ammonia, alkenes, and alkanes.

Competency 5.5 Students will be able to give the reagents and the equations for the preparation of alkynes from alkyl halides via elimination reactions and displacement reactions for chain lengthening.

Competency 5.6 Students will be able to give the reaction products of alkynes when given the reactants and reaction conditions:

A. Reaction of terminal alkynes with Cu<sup>2+</sup>, Ag<sup>+</sup>, NaNH<sub>2</sub> or organolithium compounds

B. Reduction with H<sub>2</sub> on a catalyst, or Na in NH<sub>3</sub>

C. Electrophilic addition of HX, X<sub>2</sub>, H<sub>2</sub>O

D. Radical addition of HBr

E. Nucleophilic addition of alkoxides R-O

F. Hydroboration followed by:

1. Protonolysis (cis addition of H<sub>2</sub> to form alkene)

2. Oxidation (anti-Markovnikov addition of H<sub>2</sub>O to yield aldehydes and ketones)

## G. Oxidation reactions

1.  $\text{KMnO}_4$  - formation of diketones
2.  $\text{KMnO}_4$  - cleavage of carboxylic acids

Competency 5.7 Students will be able to recognize, give or complete equations for the preparation of alcohols.

Competency 5.8 Students will be able to give the reaction equations for the conversion of alcohols to alkyl halides, alkyl ethers, or alkenes, and the mechanism for each conversion.

Competency 5.9 Students will be able to recognize, give, or complete equations for the preparation of ethers and the reaction of ethers.

**Outcome 6** - Students will be able to demonstrate an understanding of the various laboratory techniques including spectroscopic methods used in organic chemistry. Spectroscopy emphasis will be placed on interpretation of spectroscopic data (i.e. Fourier-Transform Infrared (FTIR), Proton Nuclear Magnetic Resonance,  $^{13}\text{C}$  Nuclear Magnetic Resonance, Mass Spectroscopy) to determine basic functional groups present in a molecule and the arrangement of those groups in simple organic molecules.

Competency 6.1 Students will be able to identify the various parts of the FTIR.

Competency 6.2 Students will be able to generate a spectrum from the FTIR spectrometer and interpret the resultant data.

Competency 6.3 Students will be able to interpret Proton Nuclear Magnetic Resonance ( $^1\text{H}$ -NMR) to assist in determining structural arrangements of functional groups in an organic compound.

Competency 6.4 Students will be able to interpret Carbon-13 Nuclear Magnetic Resonance ( $^{13}\text{C}$ -NMR) to assist in determining structural arrangements of functional groups in an organic compound.

Competency 6.5 Students will be able to interpret Mass Spectroscopy to assist in determining structural arrangements of functional groups in an organic compound.

Competency 6.6 Students will be able to perform basic organic laboratory techniques of synthesis, extraction, purification, identification.

Competency 6.7 Students will be able to draw conclusions from experimental evidence and express those conclusions them in written form.

Competency 6.8 Students will be able to use data to support experimental findings.

Competency 6.9 Students will be able to demonstrate a practical knowledge of appropriate handling of chemicals and chemical disposal methods, including utilizing information found on an MSDS.