

Organic Chemistry I and II challenge exam

Dear student:

Organic Chemistry I and II at LCSC covers the standard one year organic curriculum and students take the two-semester ACS exam as their spring final. You can challenge either or both Organic Chemistry I and II by taking the ACS organic exams. If you would like to challenge Organic Chemistry I, you will take the first semester ACS exam. If you would like to challenge Organic Chemistry II, you will take the second semester ACS exam. If you wish to challenge both classes, you will need to take both tests. In any case, a score of at least 50th percentile is a successful challenge of the class(es) and will earn you credit and a Pass grade. For a score below the 50th percentile, you will not earn credit. Depending on the version of the exam, the 50th percentile is usually a raw score of between 33 and 40 out of 70 questions.

An overview of the topics covered on the Organic Chemistry exam are available here:

<http://uwm.edu/acs-exams/study-guides/organic-chemistry/> and study guides with sample questions are available from the same website. You can also borrow the study guide from the Math and Science Tutoring Center. Additional problems for practice are here:

<https://www2.chemistry.msu.edu/faculty/reusch/virttxtjml/questions/problems/indexam.htm> and <https://chemistry.boisestate.edu/richardbanks/organic/mc/mcquestions317.htm> .

A more detailed list of topics covered in Organic Chemistry I and II at LCSC is attached.

If you have any questions, please contact me.

Best,

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Professor of Chemistry

Organic chemistry learning outcomes

- Sketch a given atom including protons, electrons, valence electrons, neutrons, electron shells
- Use the periodic table to make a model of a given atom, determine relative electronegativity and predict number of bonds that an element will form
- Define and state the significance of atomic number, atomic mass and mass number
- Define and utilize the following terms: Isomer, VSEPR, electronegativity, polarity, resonance, valence bond theory
- Identify covalent, polar covalent and ionic bonds. Also identify polar protic, polar aprotic and nonpolar bonds
- Draw Lewis structures, predict the shape and polarity of a molecule, calculate formal charge
- Draw resonance structures for given structures
- Use curved arrow notation to show flow of electrons
- Distinguish between resonance structures and isomers
- Label hybrid orbitals with sp^3 , sp^2 or sp and predict bond length and strength using %s character
- Convert between expanded, condensed and line structures, recognize formal charges without calculating
- Given pK_a , predict whether an acid/base reaction will occur as written
- Predict the relative acidity of different molecules and which proton in a particular molecule is most acidic using inductive effects, resonance, hybridization effects, element effects
- Predict the most acidic proton in a molecule and the most acidic molecule in a group.
- Clearly rationalize your choice of most acidic proton/molecule based on differences in elements, inductive effects, resonance and hybridization.
- Define functional group.
- Identify functional groups in any molecule (you MUST memorize the functional group names – make flash cards if they help you).
- Recognize the importance of functional groups in molecules.
- Identify nucleophiles and electrophiles as a part of functional groups and use curved arrow notation to show flow of electrons between them.
- Identify and distinguish between van der Waal's forces, dipole-dipole interactions and hydrogen bonding.
- Explain what changes occur at the molecular level when materials change phase.
- Identify gases, liquids and solids by their differences in intermolecular forces.
- Identify hydrophobic and hydrophilic parts of molecules.
- Predict solubility, relative melting point and boiling point and clearly rationalize your answer.
- Explain why "like dissolves like."

- Explain how soap cleans
- Explain how molecule structure leads to the phospholipid bilayer and micelle shape
- Explain the roles and importance of the cell membrane
- Calculate degree of unsaturation for hydrocarbons
- Be able to quickly draw isomers based on the degree of unsaturation
- Label primary, secondary, tertiary Cs and Hs
- Name alkanes and cycloalkanes, including cis and trans.
- Define steric strain, torsional strain, angle strain and 1,3-diaxial interactions.
- Identify different types of strain in molecules.
- Distinguish between stereoisomer and conformer
- Use Newman projections to draw staggered and eclipsed alkanes
- Determine the most stable conformation of an alkane and cycloalkane.
- Use energy costs of interactions to construct a graph of strain energy as a function of conformation.
- Draw cyclohexane in the chair conformation.
- Draw two conformations of substituted cyclohexanes (ring flip).
- Determine which conformation of a substituted cyclohexane is most stable and rationalize your choice by referring to figures of the cyclohexanes.
- Write a balanced combustion reaction.
- Identify oxidations and reductions in organic reactions.
- Distinguish between and define: constitutional isomers, enantiomers, diastereomers, meso compounds and conformers.
- Identify chiral centers and assign absolute configuration.
- Explain how R/S and d/l/+/- are different and how they are similar.
- Explain how chiral compounds effect plane polarized light.
- Discuss the physical, chemical and biological properties of enantiomers and diastereomers (for example: mp, bp, solubility, optical activity, polarity, reactivity and interaction with enzymes and receptors in the body).
- Understand standard notation for writing chemical reactions.
- Identify addition, elimination and substitution reactions.
- Define reaction mechanism, concerted reaction, stepwise (or multistep) reaction, reactive intermediate, radical reaction, polar reaction, homolysis, heterolysis, homogenesis and heterogenesis and identify examples.
- Identify radical carbons, carbocations and carbanions.
- Use arrows appropriately to represent reaction, equilibrium, resonance, polar reactions and radical reactions.
- Distinguish between kinetics and thermodynamics
- Describe the significance of thermodynamic equations ($\Delta G^\circ = -RT\ln K_{eq}$ and $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$).
- Use $\Delta G^\circ = -RT\ln K_{eq}$ to calculate the quantity of product at equilibrium.

- Interpret a reaction diagram. Be able to label: products, reactants, transition states, intermediates, activation energy and also determine the number of reaction steps.
- Use bond dissociation energies to estimate the spontaneity of a reaction.
- Describe the connections between collisions and kinetics.
- Predict how temperature changes, concentration and catalysts effect reaction rate using collision theory.
- Explain how rate equations can be used to predict reaction mechanism (in particular, the number of steps in a reaction).
- Label primary, secondary and tertiary alkyl halides.
- Label examples of vinylic, allylic, aryl and benzylic organohalides.
- Predict relative physical properties of alkyl halides and alkanes.
- Recognize the general reactions of alkyl halides: substitution and elimination.
- Label the nucleophile, electrophile and leaving group in a substitution reaction.
- Use pK_a units to predict whether or not a particular S_N2 reaction will occur.
- Identify basic characteristics of an S_N2 reaction: number of mechanistic steps, inversion of configuration, rate law, components (nucleophiles, electrophiles, leaving group).
- Classify nucleophiles and leaving groups as good or poor.
- Identify double bonds as monosubstituted, disubstituted, etc.
- Arrange alkenes in order of stability.
- Write mechanisms for E1 and E2 reactions.
- Predict the products of E1 and E2 reactions including stereochemistry as a result of an antiperiplanar transition state.
- Explain why E1 reactions are not as useful as E2 reactions (C^+ rearrangements and competition with S_N1 reactions).
- Predict whether a reaction will be E1, E2, S_N1 or S_N2 .
- Be able to write reactions and reaction mechanisms for E1, E2, S_N1 or S_N2 involving alcohols, ethers and epoxides.
- Use reagents such as acid, $POCl_3$, $SOCl_2$, $TosCl$ and PBr_3 to make $-OH$, ethers and epoxides react in elimination and substitution reactions.
- Predict products, including stereochemistry, of reactions involving alcohols and $SOCl_2$, $TosCl$ and PBr_3 .
- State, us and rationalize Zaitsev's rule.
- Arrange carbocations in order of stability.
- Predict products of carbocation rearrangements and explain why they occur.
- Explain the role of benzo[a]pyrene in causing cancer.
- Label double bonds as E/Z and cis/trans.
- Explain why ethene is important in society today.
- Fill in the blanks (either reactants, reagents or products) for the following reactions:
 - Elimination reactions to prepare alkenes.

- Addition reactions of alkenes
 - Hydrohalogenation
 - Hydration
 - Halogenation
 - Halohydrin formation
 - Hydroboration-oxidation
- Explain stereochemistry and regiochemistry of a reaction using mechanisms of the reactions listed above.
- Explain the significance of chemical shift (ppm), multiplicity and integration in NMR.
- Use ^{13}C chemical shifts to propose reasonable structures.
- Construct a table of ^1H -NMR chemical shifts (ppm), multiplicities, integrations and assignments. Use the table to propose a reasonable structure.
- Use IR, MS and NMR to propose structures from raw data.
- Identify conjugated molecules.
- Rationalize the basic characteristics of conjugated molecules:
 - Unusually short single bonds
 - More stable than molecules with isolated double bonds
- Predict which conjugated molecule will absorb at a higher wavelength in UV/vis spectroscopy.
- Understand how observed color connects to absorbed color.
- Draw resonance structures for any given molecule or ion.
- Propose a reasonable resonance hybrid.
- Select which resonance structures contribute the most to a resonance hybrid.
- Construct molecular orbital diagrams of simple molecules.
- Interpret the significance of molecular orbital diagrams (bond lengths, connections to resonance, etc).
- Predict products of Diels-Alder reactions.
- Identify which molecules would be most reactive in a Diels-Alder reaction.
- Identify key features of benzene and other aromatic molecules such as planarity, conjugation, resonance, cyclization, $4n+2$ pi electrons, reactivity.
- Name substituted benzenes, including the non-IUPAC names: phenol, toluene and aniline.
- Describe how heat of hydrogenation can be used to show the unusual stability of benzene.
- Identify molecules that are aromatic, including molecules that contain charges and heteroatoms,
- Understand the molecular orbital basis of aromaticity.
- Sketch molecular orbital energy diagrams for cyclic molecules.
- Propose mechanisms and fill in the blanks (either reactants, reagents or products) for the following reactions, and use them in synthesis:
 - Halogenation

- Nitration
- Sulfonation
- Friedel-Crafts alkylation and acylation
- Rationalize why a substituent is electron withdrawing or donating, including distinguishing between resonance and inductive effects.
- Predict the products of electrophilic aromatic substitution of substituted benzenes.
- Rationalize substituent effects using a combination of words and figures.
- Propose valid synthetic routes to prepare multi-substituted benzenes.

- Draw keto-enol tautomers and explain how and why they occur
- Explain why terminal alkynes are more acidic than alkenes and alkanes
- Define retrosynthesis, target molecule, multistep synthesis, starting material.
- Recognize and label reactions as oxidation and reduction
- Fill in the blanks (either reactants, reagents or products) for the following reactions:
 - Reduction of alkenes to give alkanes
 - Reduction of alkynes to give alkanes, cis or trans alkenes
 - Reduction of C-X bonds
 - Epoxidation of alkenes
 - Oxidative cleavage of alkenes and alkynes
 - Oxidation of alcohols
- Predict the cis/trans stereochemistry of epoxidation reactions (*not* the Sharpless epoxidation)
- Predict the product of oxidations of alcohols based on whether the alcohol is primary, secondary or tertiary and explain why oxidation of tertiary alcohols does not occur.
- Recognize radicals and radical reactions.
- Distinguish radical reactions from polar reactions.
- Draw resonance structures of radical molecules.
- Arrange radicals in order of stability.
- Predict which radical will be formed based on stability.
- Predict products of radical chlorination and bromination.
- Explain why chlorination is not regioselective but bromination is regioselective.
- Propose reasonable initiation, propagation and termination steps.
- Use radical chlorination and bromination in synthesis.
- Explain how the ozone hole formed, why it's important and how new molecules are designed to avoid damaging the ozone hole further.
- Identify and explain the action and significance of antioxidants.
- Explain how polymers are formed from monomers in radical reactions.
- Predict the polymer that will form from a given monomer.

- Predict whether a carbonyl compound will undergo nucleophilic addition or substitution and rationalize your choice.
- Propose mechanisms and fill in the blanks (either reactants, reagents or products) for the following reactions, and use them in synthesis:
 - Grignard reaction (magnesium and lithium)
 - Organocuprate reaction
 - Reduction of carbonyls using metal hydrides or catalytic hydrogenation
 - Oxidation of aldehydes and ketones using chromium compounds (you do not need to know the mechanism here).
- Name simple aldehydes and ketones.
- Compare properties such as boiling point, melting point and solubility of aldehydes and ketones to other functional groups.
- Apply LeChatelier's principle to the formation of a hydrate.
- Recognize carbohydrates, explain their role in the carbon cycle and explain how they convert between linear and cyclic form.
- Propose mechanisms and fill in the blanks (either reactants, reagents or products) for the following reactions, and use them in synthesis:
 - Reaction of a carbonyl with H^- (from NaBH_4 or LiAlH_4) $^- \text{CN}$, and water.
 - The Wittig reaction
- Identify types of carboxylic acid derivatives (amide, ester, anhydride, acid chloride).
- State whether an acid-base, or nucleophilic addition-elimination would occur for a given reaction.
- Propose mechanisms and fill in the blanks (either reactants, reagents or products) for the interconversion of carboxylic acid derivatives.
- Understand the significance of acid chlorides and anhydrides in synthesis.
- Explain why some carboxylic acid derivatives are more reactive than others, and how this affects synthesis.
- Predict products and write mechanisms for reactions at the alpha carbon of carbonyls including:
 - *Hell-Volhard-Zelinsky*
 - Direct alkylation
 - Indirect alkylation via enamines
 - *Acetoacetic Ester Synthesis*
 - *Malonic Ester Synthesis*
 - *Aldol reaction/condensation*
 - Crossed aldol
 - Claisen and crossed Claisen
 - Michael addition