COURSE OBJECTIVES / OUTCOMES / COMPETENCIES. By the end of the course, students should be able to do the following:

- See Test1-4 Objectives/Competencies as listed in the syllabus and on the main course website for more detailed listing of course objectives.

1. **Predict and explain Patterns and Properties**. Predict and explain patterns in shape, structure, bonding, hybridization, formal charge, stability, acidity, basicity, solubility, and reactivity for hydrocarbons, halocarbons, alkenes, dienes, and arenes, by understanding and applying concepts of organic chemical structure and bonding and stability.
2. **Predict reaction products**. Be able to predict products, including stereochemistry, in the reactions of alkanes, halocarbons, alkenes, dienes, and arenes.
3. **Classify, explain, and apply fundamental reactions.** Be able to recognize, classify, explain, and apply fundamental organic reactions such as S_N2, S_N1, E2, E1, alkene addition, electrophilic aromatic substitution, 1,2/1,4-additions, ring-opening, and radical halogenation. Be able to apply concepts associated with these general reaction types to product prediction, synthesis design, and reaction mechanism.
4. **Retrosynthetic analysis and Synthesis Design**. Use retrosynthetic analysis to design efficient multi-step syntheses involving halocarbons, alkenes, and arenes as intermediates or final products
5. **Draw Mechanisms.** Draw logical and detailed mechanisms for various fundamental reactions of alkanes, halocarbons, alkenes, dienes, and arenes.
6. **Apply Resonance and Conjugation.** Predict and explain patterns in stability, shape, hybridization, reactivity, and product formation when resonance or conjugation applies to a reactant, intermediate, or final product.
7. **Recognize Stereochemistry.** Classify molecules as chiral or achiral, identify chiral carbons as (R) or (S), identify relationships between pairs of molecules as enantiomers, diastereomers, or equivalent, and identify when a solution is racemic versus optically active.
8. **Apply Stability-Reactivity Principles**. Predict, explain, and rank the relative speeds of different chemical reactions by applying structure-dependent patterns in stability combined with application of mechanism recognition.
9. **Recognize Structure Relationships Between Chemicals**. Be able to recognize relationships between two chemical structures as the same structures, resonance structures, structural isomers, enantiomers, or diastereomers.
10. **Use Nomenclature**. Provide correct IUPAC names for alkanes, halocarbons, alkenes, and aromatics, including cyclic molecules and including stereochemistry.
11. **Recognize and Apply Functional Groups**. Classify organic molecules by their functional groups, and identify fundamental properties associates with those functional groups.
12. **Demonstrate Understanding in Scenarios Involving Alkanes, Alkenes, Alkyl Halides, Dienes, and Arenes.** Answer questions and explain/predict/apply physical properties, nomenclature, synthesis, reactions, mechanisms, and synthesis design/retrosynthesis to scenarios involving alkanes, alkenes, alkyl halides, dienes, and arenes.

Instructional Materials: Detailed class notes; video lectures; in-lecture practice/application problems; supporting supplemental videos; videos talking/teaching through the process for processing/answering each practice problem in the practice sets; feedback and tutorials within Sapling online homework; videos talking through the process for processing/answering each of the practice test case study problems; textbook readings; textbook problems; solutions manual explaining/teaching the process for processing/answering practice problem in the book homework.

Activities/Practice: The course includes an extensive and diverse range of activities ("practice problems") to enable students to apply what they are learning, to practice the types of skills they will need, and to effectively prepare for the tests. These activities include: 1. Extensive in-lecture in-notes practice problems; 2. Practice sets online (≥4 per test; 3. Practice Tests (≥3 per test); 4. Sapling online homework problems; 5. "Quizzes" (open notes, take-home); and 6. Textbook practice problems. Of these the Sapling online homework and the "quizzes" are required and graded. All of the others have answer keys available. For practice sets and practice tests, online videos are provided walking through each problem. Of these, the Sapling online homework and the quizzes will be required and count towards your grade.

Self-Assessment: How do you know if you're mastering the material, and are eventually going to be prepared to score well on the tests? See whether you are consistently understanding and correctly answering the problems in the:
1. In-lecture problems; 2. Practice sets online; 3. Practice Tests; 4. Sapling online homework problems; and 5. Book practice problems.

Graded Assessment (Required Work): 1. Sapling online homework 2. Quizzes. 3. Tests.

- The test scores will make up 80% of the class points. Sapling and the quizzes will combine for the other 20%.

TEST ONE SKILLS/OBJECTIVES / OUTCOMES / COMPETENCIES

Ch		**TEST ONE**	**Self-Assessment** (Some but not all Graded)	**Graded Assessment**
1	Structure Determines Properties	1. Identify number of bonds and lone pairs for uncharged 2nd-row atoms 2. Draw and interpret Lewis, condensed, and line-angle structural formulas, including those involving double or triple bonds. 3. Recognize when covalent versus ionic bonding exists 4. Recognize and calculate formal charges and lone pairs given bond connectivity 5. Populate lone pairs given formal charges and bond connectivity 6. Identify and draw resonance structures, and use them to predict stabilities. 7. Use arrow-pushing to display electron movement between resonance structures 8. Use principles of electronegativity to predict bond polarity, predominant resonance form, anion stability, anion basicity, and acidity 9. Use arrow-pushing to display electron movement in chemical reactions 10. Identify acids and bases, and predict whether an acid-base equilibrium will favor products or reactants 11. Predict relative acidities and basicities based on structure, bonding, charge, electronegativity, and resonance of conjugate acid-base pairs.	1. In-lecture in-notes problems 2. Practice sets online 3. Practice Tests 4. Sapling homework problems 5. Book practice problems	1. Sapling homework 2. Quiz 1 and Quiz 2 3. Test 1 4. Final Exam
2	Alkanes and Cycloalkanes: Introduction to Hydrocarbons	12. Predict the hybridization, electron geometry, and approximate bond angles relative to atoms in a molecule 13. Identify sigma versus pi bonds, and rank bond strengths 14. Draw 3-dimensional representation of given molecules, using the hash-wedge convention. 15. Identify polar and nonpolar molecules, and predict which ones can engage in hydrogen-bonding. 16. Predict general trends in the boiling points and solubilities of compounds, based on their size, polarity, and hydrogen-bonding ability. 17. Identify the classes of compounds, the "functional groups", including hydrocarbons and organic molecules containing oxygen or nitrogen, and draw structural formulas for examples 18. Identify when pairs of structures are related as structural isomers, stereoisomers, resonance structures, or as the same. 19. Correctly name alkanes and cycloalkane 20. Given the name of an alkane, draw the structure and give the molecular formula	1. In-lecture in-notes problems 2. Practice sets online 3. Practice Tests 4. Sapling homework problems 5. Book practice problems	1. Sapling homework 2. Quiz 2 3. Test 1 4. Final Exam
3	Alkanes and Cycloalkanes: Conformation and cis-trans Stereoisomers	21. Use Newman projections to compare the energies of alkane conformations 22. Draw best and worst Newman projections relative to any individual bond 23. Use torsional and steric strain terminology to explain differences in rotation barriers and in Newman-projection stabilities 24. Identify, name, and draw cis and trans stereoisomers of di-substituted cycloalkanes 25. Compare the energies of cycloalkanes, and explain ring strain 26. Draw accurate cyclohexane chair conformation, including cis- or trans- di-substituted cases, and including "left-" and "right-handed" chair conformations 27. Illustrate and identify axial versus equatorial substituents on cyclohexane chairs; and predict the most stable conformations of di-substituted cases. 28. Based on chemical formula, identify whether an alkane is cyclic or acyclic 29. Given a chemical formula for an alkane, draw and name structural isomers	1. In-lecture in-notes problems 2. Practice sets online 3. Practice Tests 4. Sapling homework problems 5. Book practice problems	1. Sapling homework 2. Test 1 3. Final Exam

TEST TWO SKILLS/OBJECTIVES / OUTCOMES / COMPETENCIES

Ch		**TEST TWO**	**Self-Assessment** (Some but not all Graded)	**Graded Assessment**
4	Alkyl Halides and An Overview of Chemical Reactions	1. Draw the mechanism and explain the energetics of the propagation steps in the free-radical halogenation of alkanes 2. Based on the selectivity of halogenation and the varying stabilities of 1º, 2º, 3º, and allylic radicals, predict the products of halogenation of hydrocarbons 3. Apply principles of bond strength to predict whether overall reactions or individual steps within a multi-step mechanism are exothermic or endothermic, are favorable or unfavorable, and use bond strengths to predict the energetics of reactions. 4. Given a rate law, predict how the rate would vary with changes in solute concentrations or solvent volume. 5. Use energy diagrams to discuss transition states, activation energies, intermediates, and the rate-determining step of a multistep reaction 6. Rank the stabilities of different radical, carbocations, or anions and describe or explain the structural features that stabilize them. 7. Use reactant and product stability-reactivity principles in conjunction with structural factors to compare the relative reactivities of different reactions 8. Predict and explain variations in bond strengths	1. In-lecture in-notes problems 2. Practice sets online 3. Practice Tests 4. Sapling homework problems 5. Book practice problems	Sapling homework Quiz 3 Test 2 Final Exam
5	Stereochemistry	9. Classify moleculas as chiral or achiral, and identify mirror planes of symmetry 10. Draw a mirror image for any molecule 11. Identify chiral carbons, and name them using the (R) and (S) convention 12. Identify relationships between pairs of molecules as enantiomers, diastereomers, or equivalent 13. Identify and identify meso compounds 14. Draw all stereoisomers for a given structure 15. Identify when a solution is racemic versus optically active 16. Identify when a chemical reaction will give a racemic versus optically active product Recognize and explain how various physical properties might vary or not vary for enantiomers, or for diastereomers.	1. In-lecture in-notes problems 2. Practice sets online 3. Practice Tests 4. Sapling homework problems 5. Book practice problems	Sapling homework Quiz 4 Test 2 Final Exam
6	Reactions of Alkyl Halides; Nucleophilic Substitutions and Eliminations	17. Correctly name alkyl halides, and identify halocarbons as 1º, 2º, 3º, allylic, vinyl, or aryl 18. Predict the products of S_N2 reactions, including stereochemistry. 19. Predict the products of S_N1 reactions, including stereochemistry. 20. Predict the products of E1 and E2 reactions, including stereochemistry. 21. Use Zaytsev's Rule to predict which structural isomer will predominate in E2 or E1 reactions. 22. When a halocarbon reacts, identify when S_N2 or E2 reactions occur, or when S_N1 or E1 reactions will occur, and predict the major products. 23. Draw mechanisms for any of S_N1, S_N2, E1, or E2 reaction 24. Rank the relative rates of substitutions or eliminations reactions, based on differences in substrate, base/nucleophile, leaving group, or solvent. 25. Predict whether a reaction will be first-order or second-order 26. When possible, predict predominance of substitution or elimination 27. Identify reactants that could product target chemical products 28. Design multi-reaction synthesis design sequences to convert hydrocarbons to more highly functional derivatives	1. In-lecture in-notes problems 2. Practice sets online 3. Practice Tests 4. Sapling homework problems 5. Book practice problems	Sapling homework Test 2 Final Exam

TEST THREE SKILLS/OBJECTIVES / OUTCOMES / COMPETENCIES

		TEST THREE	**Self-Assessment** (Some but not all Graded)	**Graded Assessment**
7	Alkenes: Structure and Preparation: Elimination Reactions	1. Calculate "elements of unsaturation" ("EU") for any formula. 2. Determine the number of alkenes and rings present in any formula, given its chemical formula and hydrogenation information. 3. Draw possible structural isomers for a chemical, given formula and hydrogenation information. ("Detective" problems.") 4. Draw and name all alkenes with a given molecular formula 5. Use the E-Z and cis-trans systems to name stereoisomers 6. Use heats of hydrogenation to compare stabilities of alkenes, or use stability patterns for alkenes to predict heats of hydrogenation or heats of combustion 7. Predict relative stabilities of alkenes and cycloalkenes, based on structure and stereochemistry 8. Predict the products of E2-elimination for haloalkanes, reactions (Zaytsev versus Hofmann elimination), depending on whether the base used is bulky or normal. 9. Predict the distribution between E2-elimination and S_N2 substitution for reactions of haloalkanes 10. Predict the major alkene products (Zaytsev elimination) when alcohols undergo acid-catalyzed dehydration. 11. Propose and draw detailed mechanisms for E2-elimination reactions of alkyl halides, and for acid-catalyzed E1 elimination of alcohols. 12. Propose and design effective single-step and multistep syntheses of alkenes. (Synthesis design problems.)	1. In-lecture problems 2. Practice sets online 3. Practice Tests 4. Sapling homework problems 5. Book practice problems	Sapling homework Test 3 Final Exam
8	Alkenes: Addition Reactions and Other Alkene Reactions	13. Predict the product when an alkene react with a hydrogen halides 14. Predict the products when alkenes react with HBr/peroxides 15. Predict the product when an alkene react with H_2O/H^+ 16. Predict the product when an alkene undergoes hydroboration/oxidation 17. Predict the products when alkenes undergoes oxymercuration/demercuration 18. Predict the product when an alkene undergoes hydrogenation 19. Predict the product when an alkene reacts with Cl_2 or Br_2 20. Predict the product when an alkene reacts with Cl_2 or Br_2 in the present of water 21. Predict the product when an alkene undergoes expodiation, with or without water present 22. Predict the product when an alkene undergoes ozonolysis 23. In all of the above reactions, include effective consideration of reaction orientation (Markovnikov versus anti-Markovnikov orientation), and stereochemistry 24. Predict when a reaction will produce achiral versus chiral products 25. Predict the correct stereoisomers for stereospecific reactions. 26. **Draw detailed logical mechanisms** for alkene reactions with HBr, H_2O/H^+, Br_2, or Br_2/H_2O. **27. Use retrosynthetic analysis to solve multi-step synthesis design problems involving alkenes as intermediates or final products** 28. Use clues provided by products of reactions such as ozonolysis to determine the structure of an unknown alkene 29. Determine the stereochemistry of a starting alkene, given reactants and the product stereochemistry.	1. In-lecture problems 2. Practice sets online 3. Practice Tests 4. Sapling homework problems 5. Book practice problems	Sapling homework Test 3 Final Exam

TEST FOUR SKILLS/OBJECTIVES / OUTCOMES / COMPETENCIES

		TEST FOUR	**Self-Assessment** (Some but not all Graded)	**Graded Assessment**
15	Conjugation in Alkadienes and Allylic Systems	1. Recognize when conjugation applies, how it impacts chemical stability, and use it to predict and rank stabilities of various substances 2. For compounds containing nitrogen atoms, determine what the nitrogen atom hybridization and shape is; determine what the lone pair hybridization is; and predict whether the nitrogen basicity is normal or low 3. Predict and rank how various reactions and their reaction rates are impacted by conjugation/resonance, whether in a reactant or an intermediate or a product, for example in SN1 reactions, radical reactions or acid-base reactions 4. Predict the products of hydrogen halide additions to conjugated dienes. 5. Identify 1,2 vs 1,4 addition products in hydrogen halide additions to conjugated dienes 6. Identify thermodynamic versus kinetic products 7. Predict the products of allylic radical bromination reactions. 8. Draw mechanisms for addition reactons or SN1 reactions proceeding through allylic cations 9. Draw resonance structures for allylic cations, radicals, or anions 10. Predict the products of Diels-Alder reactions, including stereochemistry; and when the dienophile is disubstituted. 11. Identify reactants involved in Diels-Alder reactions, allylic bromination reactions, and hydrogen halide additions to conjugated dienes.	1. In-lecture problems 2. Practice sets online 3. Practice Tests 4. Sapling homework problems 5. Book practice problems	Sapling homework Test 4 Final Exam
16	Arenes and Aromaticity	12. Name aromatic molecules, and draw structures given names 13. Use the polygon rule to draw the energy diagram for a cyclice system of p orbitals, and fill in the electrons to show whether a given compound or ion is aromatic or anti-aromatic 14. Use Huckel's rule to identify whether a given structure is aromatic, anti-aromatic, or non-aromatic, including heterocycles and ions 15. Apply understanding of how aromaticity or anti-aromaticity in a reactant, intermediate, or product impacts reactivity and reaction rates, for example in SN1 reactions or acid-base reactions 16. For compounds containing nitrogen atoms, determine what the nitrogen atom hybridization and shape is; determine what the lone pair hybridization is; and predict whether the nitrogen basicity is normal or low	1. In-lecture problems 2. Practice sets online 3. Practice Tests 4. Sapling homework problems 5. Book practice problems	Sapling homework Test 4 Final Exam
17	Reactions of Arenes: Electrophilic Aromatic Substitution	17. Predict products for the common electrophilic aromatic substitutions: halogenation, nitration, sulfonation, alkylation, and acylation. 18. Predict the position of substitution involving rings that have more than one substituent. 19. Draw the mechanisms for the electrophilic aromatic substitution reactions. 20. Draw resonance structures for the cationic intermediates involved in electrophilic aromatic substitution reactions on substituted rings. 21. Identify and apply which substituents are electron donors and electron withdrawers; activators versus deactivators; and ortho/para directors versus meta directors for electrophilic aromatic substitution reactions. 22. Predict products and utilize in synthesis design problems the common aromatic support reactions: reduction of nitro groups to amino; reduction of acyl group to 1º alkyl; oxidation of alkyl groups to carboxyl; desulfonation; allylic bromination. 23. Retrosynthesis/Synthesis design: design syntheses towards specific aromatic targets with appropriate ortho, meta, or para subsitution, by using appropriate reactants and appropriate reaction sequencing	1. In-lecture problems 2. Practice sets online 3. Practice Tests 4. Sapling homework problems 5. Book practice problems	Sapling homework Test 4 Final Exam