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. **Nomenclature**. Provide correct IUPAC names for alcohols, aldehydes, ketones, amines, carboxylic acids, and esters.
2. **Predict and explain Patterns and Properties**. Predict and explain patterns in structure, hybridization, acidity, basicity, solubility, and reactivity for alcohols, aldehydes, ketones, amines, carboxylic acids, acid chlorides, anhydrides, esters, and amides by understanding and applying concepts of organic structure and bonding and stability.
3. **Acid-Base**: Predict, rank, and apply acidities of carboxylic acids, phenols, water, alcohols, ketones, esters, 1,3-dicarbonyls, and ammoniums, and predict, rank, and apply basicities of their conjugate bases, relative to other acids and bases. Apply the impact of electron donors or withdrawers, and the impact of lone-pair hybridization.
4. **NMR:** Demonstrate understanding of fundamental 1D Nuclear Magnetic Resonance spectroscopy. This will include being able to solve for chemical structure given an H-NMR or C-NMR spectrum and a molecular formula; being able to predict 1H-NMR chemical shifts, splitting and integration; being able to predict C-NMR chemical shifts; being able to diagnose NMR equivalence and non-equivalence; being able to demonstrate fluency in the terminology of NMR; and being able to use Infrared Spectroscopy to identify characteristic functional groups.
5. **Predict reaction products**. Be able to predict products in the reactions of alcohols, aldehydes, ketones, amines, carboxylic acids, acid chlorides, anhydrides, esters, and amides.
6. **Synthesis Reactions**: Demonstrate understanding of reactions and reaction pathways involved in the synthesis of alcohols, aldehydes, ketones, amines, carboxylic acids, acid chlorides, anhydrides, esters, and amides.
7. **Draw Mechanisms.** Draw logical and detailed mechanisms for various fundamental reactions involving alcohols, aldehydes, ketones, amines, carboxylic acids, acid chlorides, anhydrides, esters, and amides.
8. **Synthesis Design**: Given a starting chemical, suggest reactants or sequences of reactions/reactants that could transform the starting material into a target product.
9. **Retrosynthetic analysis and Synthesis Design**. Use retrosynthetic analysis to design efficient one-step or multistep syntheses involving alcohols, aldehydes, ketones, amines, carboxylic acids, acid chlorides, anhydrides, esters, or amides as starting materials, intermediates or final products
10. **Classify, explain, and apply fundamental reactions.** Be able to recognize, classify, explain, and apply fundamental organic reactions such as oxidation reactions; reduction reactions; Grignard reactions; anionic additions; acid-catalyzed additions, eliminations, and substitutions; enolate reactions; hydrolysis reactions; and interconversions between carboxylic acids, acid chlorides, anhydrides, esters, and amides.
11. **Demonstrate Understanding in Miscellaneous Scenarios Involving Alcohols, Aldehydes, Ketones, Amines, Carboxylic Acids, Acid Chlorides, Anhydrides, Esters, and Amides.** Answer questions and explain/predict/apply physical properties, nomenclature, synthesis, reactions, mechanisms, and synthesis design/retrosynthesis to scenarios involving alcohols, aldehydes, ketones, amines, carboxylic acids, acid chlorides, anhydrides, esters, and amides.

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

- The following list specifies **major** skills/competencies that you may be asked to demonstrate on tests.
- The list should not be viewed as exhaustive; anything that is addressed in the notes and is not designated either in the notes or in the lectures as "not test responsible" should be considered to be fair game for test assessment.

Ch		**TEST ONE. ALCOHOL CHEMISTRY**	**Self-Assessment** (Some but not all Graded)	**Graded Assessment**
10	Structure and Synthesis of Alcohols	1. Nomenclature: Draw and name alcohols, phenols, and diols, including alkenols and cyclic alcohols; or given a name, be able to draw the structure. 2. Physical Properties: Predict and rank relative boiling points and solubilities of alcohols relative to other organic structures. 3. Predict products or specify reactants involved in the conversion of alkenes, alkyl halides, or carbonyl compounds to alcohols; and be prepared to use these transformations in multi-step synthesis scenarios, whether that be product prediction or synthesis design or retrosynthesis. 4. Grignard Reactions: Draw the expected products when organomagnesium reagents (Grignard reagents) react with aldehydes, ketones, esters (including cyclic esters), formaldehyde, or epoxides. 5. Organometallic compatibility: Identify which solvents are appropriate for use when preparing and using RMgBr reagents; identify which haloalkanes could be effectively converted to RMgBr reagents and subsequently reacted intermolecularly with other carbonyls. 6. Rank the relative reactivities of aldehydes, ketones, esters, alcohols, or water towards strong nucleophiles/bases such as RMgBr reagents. 7. Mechanisms: Use arrow-pushing to display electron movement in chemical reactions involving RMgBr, LiAlH4, or NaBH4 and aldehydes, ketones, esters (including cyclic esters), or epoxides. 8. Synthesis Design: Given a starting chemical, suggest reactants or sequences of reactions/reactants that could transform the reactant into a target product. (Presumably involving an alcohol as reactant, intermediate, or final product.) 9. Retrosynthesis: Identify different combinations of chemicals that could be used to synthesize 1º, 2º, or 3º alcohols or derivatives thereof. 10. Hydride Reduction Reactions: Predict products for reactions involving sodium borohydride or lithium aluminum hydride, including selective or non-selective reductions involving more than one carbonyl. Also be able to identify an appropriate hydride reducing agent for a particular reduction reaction.	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 3. Test 1 4. Final Exam
11	Reactions of Alcohols	11. Acid-Base: Predict and rank acidities and basicities of alcohols and alkoxides relative to other organic structures; and predict when acid/base reactions will or won't be product favored 12. Extraction: Identify and explain which chemicals will be extracted from an organic solvent into neutral water or into NaOH/water 13. Predict the products (multi-reactions sequences may be involved) for reactions sequences involving alcohols and • Reducing metals such as elemental Na or K • Bases • Oxiding agents such as PCC and H2CrO4 • Dehydrating agents such as H2SO4 or H3PO4 • Halogenating agents such as HBr, PBr3, HCl, HI, and SOCl2 (including stereochemistry) • Sulfonating agents such as TsCl and subsequent reactions 14. Chemical Tests: Identify possible structures for a chemical given a chemical formula and chemical test results (Jones, Lucas, H_2/Pt reaction…) 15. Mechanisms: Draw mechanisms for ROH → RX reactions, using HBr (or HCl or HI) or PBr3. 16. Synthesis Design: Given a starting chemical, suggest reactants or sequences of reactions/reactants that could transform the reactant into a target product. (Presumably involving an alcohol as reactant, intermediate, or final product.) 17. Retrosynthesis: Design syntheses involving different combinations of chemicals that could be used to synthesize 1º, 2º, or 3º alcohols or derivatives thereof. A limited array of possible starting chemicals will be allowed.	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

- The following list specifies **major** skills/competencies that you may be asked to demonstrate on tests.
- The list should not be viewed as exhaustive; anything that is addressed in the notes and is not designated either in the notes or in the lectures as "not test responsible" should be considered to be fair game for test assessment.

Ch		**TEST TWO Nuclear Magnetic Resonance Spectroscopy and Infrared**	**Self-Assessment** (Some but not all Graded)	**Graded Assessment**
13	Nuclear Magnetic Resonance Spectroscopy	1. Given a structure, determine which protons or which carbons are equivalent and which are nonequivalent 2. Given a structure, predict the approximate chemicals shifts for the hydrogens or the carbons 3. Use integrals to determine the relative numbers of different types of protons. 4. Use proton spin-spin splitting patterns, combined with integration and chemicals shifts, to determine the structure of alkyl and other groups and to track as far as possible from one end of a molecule. 5. Given a chemical structure, predict the approximate integration, chemical shift, and splitting for each hydrogen signal set. 6. Given a chemical structure, predict the approximate chemical shift for the carbons, and perhaps the splitting that would occur were a carbon NMR to be acquired. 7. Use integration, splitting, and chemical shifts to recognize and identify common groups, for example hydroxyl; methyl, ethyl, isopropyl, propyl; methoxy, ethoxy, isopropoxy, propoxy; methyl carbonyl, ethyl carbonyl, isopropyl carbonyl, propyl carbonyl; monosubstituted benzene, and disubstituted benzene. Given a chemical formula and an H-NMR, use the integration, chemical shifts, and splitting to solve for the structure of the chemical. 8. Distinguish overlapping signals from "clean" signal sets in an H-NMR. 9. Demonstrate and apply common terminology, such as "upfield" and "downfield"; "shielding" versus "deshielding"; and "methylene" and "methine" as well as methyl. 10. Demonstrate an understanding of the additive impact of functional groups on systems that have multiple functional groups. 11. Given a formula and a C-NMR, solve for a plausible structure of the chemical. 12. Given a formula, use whatever combination of H-NMR, C-NMR, and infrared data that is provided to solve for the structure of the chemical.	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
12	Infrared Spectroscopy	13. Given an IR spectrum or summary, identify characteristic peaks, particularly for OH and carbonyl groups 14. Distinguish whether a carbonyl is present, including whether it is saturated or unsaturated. 15. Distinguish whether an alcohol hydroxyl group is present.. 16. Given formulas with one or two oxygens present, identify which functional groups are present (such as ester; alcohol; carboxylic acid; hydroxyl ketone; ether; and saturated versus unsaturated carbonyl). 17. Match characteristic peaks with actual molecules. 18. Use IR in combination with H-NMR to solve for the structures of chemicals.	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

- The list should not be viewed as exhaustive; anything that is addressed in the notes and is not designated either in the notes or in the lectures as "not test responsible" should be considered to be fair game for test assessment.

		TEST THREE: Aldehydes, Ketones, and Enolate Chemistry	**Self-Assessment**	**Graded Assessment**
18	Ketones and Aldehydes	1. Nomenclature: Draw and name aldehydes and ketones, including in the context of multifunctional molecules where decisions about which groups are treated as substituents are necessary; or, given a name, be able to draw the structure. 2. Physical Properties: Predict and rank relative boiling points and solubilities of carbonyl compounds relative to other organic structures. 3. Carbonyl Synthesis: Process reactions for synthesis of ketones or aldehydes from alcohols, alkenes, alkynes, carboxylic acids, nitriles, acid chlorides, or aromatic compounds. This could involve predicting a product, specifying a starting material, designating an appropriate reactant, or proposing an effective synthesis. Single-step or multistep reactions may be involved. 4. Carbonyl Reactions: Predict the products for reactions (including multi-step reactions) of ketones and aldehydes with the following types of compounds: a. Hydride reducing agents (NaBH4, LiAlH4) b. Organomagnesium reagents (Grignard reagents) c. HCN d. Water under acid or base conditions (reversible hydrate formation) e. Alcohols (reversible hemiactal and acetal formation, including cyclic hemiacetals and acetals; and the reverse reactions involving acetal hydrolysis) f. Amines (reversible aminol and imine formation, including cyclic aminols and imines, and the reverse reaction involving imine hydrolysis) 5. Mechanisms: Be able to draw mechanisms for carbonyl reactions listed above, including the reverse reaction, including those involving rings. Major mechanisms include addition (anionic or acid-catalyzed), elimination, and substitution reactions. 6. Demonstrate/apply understanding of whether a mechanism is anionic or cationic. 7. Rank the relative reactivities of aldehydes, ketones, and esters. 8. Demonstrate understanding/application of protection and deprotection procedures. 9. Chemical Tests: Identify structure based on tests (including DNP and Tollens Tests) 10. Draw the starting materials that would react to produce a given product. 11. Synthesis Design: Given a starting chemical, suggest reactants or sequences of reactions/reactants that could transform the starting material into a target product. 12. Retrosynthesis: Design syntheses of targets, given a restricted pool of allowed starting materials. (Presumably involving carbonyls.)	1. In-lecture problems 2. Practice sets online 3. Practice Tests 4. Sapling homework problems 5. Book practice problems	Sapling homework Quiz Test 3 Final Exam
22	Alpha Substitutions and Condensations of Enols and Enolate	13. Acid-Base: Predict and rank acidities and basicities of ketones, esters and 1,3-dicarbonyl compounds relative to other acids and bases; predict when acid/base reactions will or won't be product favored; apply understanding of equilibria. 14. Predict when bases (hydroxide, alkoxide, versus LDA) will afford "complete" versus "small equilibrium" versus zero population of enolate anion 15. Predict the products (multi-reactions sequences may be involved) when enolate anions react with the following electrophiles: • Proton (racemization, reversible enol formation) • Halogen (including polyhalogenatin) • Alkyl halides (including usage of LDA as base) • Aldehydes/ketones (aldol reaction resulting in beta-hydroxy carbonyls; aldol condensations resulting in enones; including intramolecular versions) • Esters (Claisen reactions, including intramolecular versions) 16. Mechanisms: Draw mechanisms for each of the above reactions 17. Predict the product for reactions (including multistep reactions) involving carbonyls and phosophorus ylides (Wittig reaction) 18. Process reactions involving 1,3-dicarbonyls, including ester hydrolysis and thermal decarboxylation of 1,3-carbonyl acids. 19. Process keto-enol equilibration and mechanism, and rank amounts of enol. 20. Chemical Tests: Identify possible structures for a chemical given a chemical formula and chemical test results (including Iodoform, DNP and Tollens Tests) 21. Draw the starting materials that would react to produce a given product. 22. Synthesis Design: Given a starting chemical, suggest reactants or sequences of reactions/reactants that could transform the starting material into a target product. (Presumably either involving enolate chemistry. Synthesis of alkenes via aldol condensation or Wittig reaction will also be a priority skill.) 23. Retrosynthesis: Design syntheses of targets, given a restricted pool of allowed starting materials.	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

- The list should not be viewed as exhaustive; anything that is addressed in the notes and is not designated either in the notes or in the lectures as "not test responsible" should be considered to be fair game for test assessment.

		TEST FOUR	**Self-Assessment**	**Graded Assessment**
19	Amines	1. Nomenclature: Name amines, and draw structures given names. 2. Physical Properties: Predict and rank relative boiling points and solubilities of amines compounds relative to other organic structures. 3. Contrast physical properties of amines with those of ammonium salts. 4. Acid-Base: Predict and rank basicities of amines and acidity of ammoniums relative to other bases and acids. 5. Determine nitrogen atom hybridization and lone-pair hybridizaton; and apply to amine basicity and ammonium acidity. 6. Amine Reactions: Predict the products or identify starting materials for for reactions (including multi-step reactions) of amines, including with proton donors (acid-base); carbonys (imine formation); alkyl halides (alkylation and polyalkylation); acid chlorides (amide formation); carboxylic acids (acylation, amide formation); and carbonyl in the presence of H+/NaBH3CN (reductive amination). 7. Amine Synthesis: Demonstrate understanding of amine synthesis. This could involve predicting a product, specifying a starting material, designating an appropriate reactant, or proposing an effective synthesis. Major amine precursors include carbonyls (reductive amination; 1º, 2º, or 3º amines possible); amides (1º, 2º, or 3º amines); nitro compounds (1º); alkyl halides and ammonia (1º), and nitriles (1º). 8. Mechanisms: Be able to draw mechanisms for reactions including acid-base reactions; alkylation; polyalkylation; and acylation. 9. Draw the starting materials that would react to produce a given product. 10. Synthesis Design: Given a starting chemical, suggest reactants or sequences of reactions/reactants that could transform the starting material into a target product. 11. Retrosynthesis: Design syntheses of targets, given a restricted pool of allowed starting materials.	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
20, 21	Carboxylic Acids and Carboxylic Acid Derivatives	12. Nomenclature: Name carboxylic acids, esters, and carboxylates; and draw structures given names. 13. Physical Properties: Predict and rank relative boiling points and solubilities of carboxylic acids relative to other organic structures. 14. Acid-Base: Predict and rank acidity of carboxylic acids and basicity of carboxylates relative to other bases and acids. 15. Diagnose how electron donors or withdrawers impact acidity/basicity. 16. Determine which version of an amino acid monomer exists at different pH's 17. Carboxylic Acid Synthesis: Use chemical equations to demonstrate understanding of carboxylic acid synthesis reactions, including: hydrolysis of acid chlorides, anhydrides, esters, or amides under neutral, acidic, or basic conditions; oxidation of alcohol, alkene, or alkyl benzenes; carboxylation of Grignard reagents; hydrolysis of nitriles; or hydrolysis/decarboxylation of 1,3-diesters. 18. Carboxylic Acid Reactions: Use chemical equations to demonstrate understanding of carboxylic acid reactions, including direct or indirect conversion to acid chlorides; anhydrides; esters; amides. 19. Interconversions among Carboxylic Acids and Derivatives: Use chemical equations to predict products, identify starting materials, and design pathways for interconversions between carboxylic acids, acid chlorides; anhydrides; esters; amides, and carboxylates. 20. Mechanisms: Be able to draw mechanisms for interconversions between carboxylic acids, acid chlorides; anhydrides; esters; amides, and carboxylates, including "downhill" reactions and acid-catalyzed "lateral" conversions within the ClAvENO series. 21. Draw the starting materials that would react to produce a given product. 22. Synthesis Design: Given a starting chemical, suggest reactants or sequences of reactions/reactants that could transform the starting material into a target product. 23. Retrosynthesis: Design syntheses of targets, given a restricted pool of allowed starting materials.	1. In-lecture problems 2. Practice sets online 3. Practice Tests 4. Sapling homework problems 5. Book practice problems	Test 4 Final Exam