

GRANDE PRAIRIE REGIONAL COLLEGE
DEPARTMENT OF SCIENCE: CHEMISTRY

FORTY-THIRD SESSION 2008 – 2009

COURSE OUTLINE: ORGANIC CHEMISTRY

CH2610 A3 & B3

CH2610 A3 & B3: Organic Chemistry I; Prerequisite, CH1010 or CH1030

INSTRUCTOR: Dr. John P. Sloan
Office # J207
Phone # 539-2004
E-mail SLOAN@GPRC.AB.CA

LECTURE: CH2610 T, R 13:00 – 14:20 in D308

ALBERTA TRANSFER CREDIT

(Ref: 2008-2009 Guide to Transfer Credit at Alberta Post-Secondary Institutions)

| | |
|------------------|-------------------------------|
| GPRC: | CH2610 (3) |
| U of Alberta: | CHEM 261 (3) or AUCHE 250 (3) |
| U of Calgary: | CHEM 351 (3) |
| U of Lethbridge: | CHEM 2500 (3) |
| Athabasca U: | CHEM 350 (3) |
| Canadian UC: | CHEM 241 (4) |
| Concordia UC: | CHEM 261 (3) |

COURSE OUTLINE:

LECTURE COMPONENT:

A study of the fundamental principles of the chemistry of carbon compounds. The study is based on a reaction mechanism approach to the functional group chemistry of alkanes, alkenes, alkynes, cycloalkanes, alkyl halides, alcohols and ethers. Topics include: structure and bonding; physical properties; acidity and basicity; conformations of molecules; stereochemistry; addition, elimination and substitution reactions; structure-reactivity relationships; and introduction to methods for structure determination.

A representative selection of molecules found in agricultural, biological, environmental, industrial, medical, and pharmaceutical applications of organic chemistry will be discussed, e.g., molecules found in agrochemicals, fibres, food additives, perfumes, polymers, and prescription drugs.

LABORATORY COMPONENT:

Laboratory Techniques in organic chemistry; preparation of some organic compounds, and; methods of qualitative organic analysis.

TUTORIAL COMPONENT:

Problem solving and discussion sessions with short problem sets for completing and marking during the tutorial. In addition, weekly assignments consisting of 10 questions per assignment will be given. These assignments will consist of exam type questions and do not need to be submitted for marking. Detailed solutions to the assignments will be posted on Blackboard about 1 week after distribution.

NOTES:

- Lectures, Time and Place
CH2610 A2 T, R 13:00 - 14:20 in D308
- Laboratory Component, Time and Place
CH2610 L1 M 14:30 - 17:20 in J116
CH2610 L2 T 14:30 - 17:20 in J116
- Tutorial Component, Time and Place
CH2610 S1 F 8:30 - 9:20 in J229
CH2610 S2 F 10:00 - 10:50 in J229
- Office Hours: Individual and group assistance will normally be available in office J207 during regular college business hours outside of formal class lecture, laboratory and tutorial hours.

TEXT BOOKS AND LABORATORY ITEMS:

The following text books are required:

CH2610**Either,**

Solomons, T.W.G., and C.B. Fryhle, *Organic Chemistry*, 9th Edition, Wiley, 2008

Or,

Wade, L.G.(Jr), *Organic Chemistry*, 6th Edition, Pearson Prentice-Hall, 2006.

And

A Three Ring Binder to Hold: Sloan, J.P., *Organic Chemistry Experiments, Chemistry 2610/2630*, Grande Prairie Regional College, 2008/2009.

Molecular Models are highly recommended, namely:

Molecular Model Set for Organic Chemistry, Prentice Hall.

Study Guides and Solutions Manuals are supplementary items, namely:

1. Fernandez, J.E., and Solomons, T.W.G., *Study Guide and Solutions Manual to Organic Chemistry*, 9th Edition, 2008;
2. Simek, J.W., Wade L.G.(Jr), *Solutions Manual to Organic Chemistry*, 6th Edition.

Note:

1. All required and supplementary books, molecular structure model sets, safety glasses, and lab coats are available at the College Bookstore. *Organic Chemistry Experiments*, by J.P. Sloan, will be given as handouts in advance of each lab period. These are to be inserted in a three ring binder.

EVALUATION:

Examination Schedule and Composition of the Final Grade:

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|----|--|------|
| 1. | Midterm Exam # 1, Friday February 13 ----- | 15% |
| 2. | Midterm Exam # 2, Friday March 20 ----- | 20% |
| 2. | Final Exam to be scheduled between April 16 – 27 ----- | 35% |
| 3. | Laboratory ----- | 25% |
| 4. | Tutorial Grading Component ----- | 5% |
| | | 100% |

The Grades are based on the alpha grading system. The Registrar's Office will convert alpha grades to four-point equivalence for the calculation of grade point averages. Alpha grades, 4-point equivalence, and grade descriptors are as follows:

| Alpha Grade | 4-Point Equivalence | Descriptor |
|----------------|---------------------|-----------------------------------|
| A ⁺ | 4.0 | Excellent |
| A | 4.0 | |
| A- | 3.7 | Very Good First Class Standing |
| B+ | 3.3 | |
| B | 3.0 | Good |
| B- | 2.7 | |
| C+ | 2.3 | Satisfactory |
| C | 2.0 | |
| C- | 1.7 | Poor* |
| D+ | 1.3 | |
| D | 1.0 | Minimal Pass* |
| F | 0.0 | Failure |

* Other post secondary institutions may not award transfer credit for grades of D and D+.

Notes:

1. The Mid-Term Exams will be of 1.5 hours duration and the Final Exam will be of 3 hours duration.
2. Between 5 and 15% of exam content will be taken from a combination of weekly assignments and questions in the organic chemistry textbooks by Solomons and Fryhle, and by Wade.
3. A pass grade is essential for the Laboratory Component.
4. The Tutorial Grading Component consists of short tests at the end of each seminar and will contribute towards 5% of the final grade. A 10 question assignment will normally be given each week. To encourage general discussion and active student participation, assignment questions may be answered within, "paired teams/study groups". The assignments do not need to be submitted for grading, however, students are encouraged to complete all assignments. Detailed solutions to the assignments will be posted on Blackboard. Assistance with assignments will be given upon request.
5. Regular attendance in Lecture, Laboratory, and Tutorial Components is a Course Requirement.

Grande Prairie Regional College Calendar 2008 - 2009: Course Description (p 178).

CH2610 3(3-1-3)UT, 105 Hours, Organic Chemistry I

The correlation of structure and bonding in carbon compounds with the physical properties and chemical reactivity of organic molecules. Discussion will be based on functional groups with emphasis on hydrocarbons and derivatives that contain halogens, oxygen, sulphur and the hydroxyl group. Introduction to stereochemistry, three dimensional structure, reaction mechanisms, especially addition to double bonds, nucleophilic substitution and elimination reactions, and methods of structure determination. The study covers the functional group chemistry of alkanes, alkenes, alkynes, alcohols, ethers and sulfides.

Prerequisites: CH1010 or CH1030

Notes: Credit will be granted for only one of CH1610 or CH2610

Transfer: UA, UC, UL, AU, AF, CU, CUC, KUC

CHEMISTRY 2610: READING, STUDYING, AND PRACTICE PROBLEMS

All references are to T.W.G. Solomons and C.B. Fryhle, *Organic Chemistry*, 9th Edition, Wiley, 2008.

FALL SEMESTER

Weeks of

Jan 5 & 12: THE BASICS: Bonding and Molecular Structure

Molecular Graphic: Glycine, an organic molecule found in space

Sect # Page # Read and Study Chapter 1 "We are Star Dust"

| | | |
|---------|----|---|
| 1.1 | 2 | Organic Chemistry and Life |
| 1.2 | 3 | The Structural Theory of Organic Chemistry |
| 1.3 | 4 | Isomers: The Importance of Structural Formulas |
| 1.4 | 5 | Chemical Bonds: The Octet Rule |
| 1.5 | 7 | Writing Lewis Structures |
| 1.6 | 9 | Exceptions to the Octet Rule |
| 1.7 | 10 | Formal Charge |
| 1.8 | 13 | Resonance Theory |
| 1.8A | 15 | Summary of Rules for Resonance |
| 1.9 | 18 | Quantum Mechanics and Atomic Structure |
| 1.10 | 20 | Atomic Orbitals and Electron Configuration: |
| 1.10A | 21 | Aufbau Principle; the Pauli Exclusion Principle; Hund's Rule |
| 1.11 | 21 | Molecular Orbitals: Bonding and Antibonding |
| 1.12 | 24 | The Structure of Methane and Ethane: sp^3 Hybridization; |
| 1.12A | 24 | The Structure of Methane |
| 1.12B | 27 | The Structure of Ethane |
| 1.13 | 28 | The Structure of Ethene (Ethylene): sp^2 Hybridization |
| 1.13A | 31 | Restricted Rotation and the Double Bond |
| 1.13B | 32 | Cis-Trans Isomers |
| 1.14 | 33 | The Structure of Ethyne (Acetylene): sp Hybridization |
| 1.14A | 34 | Bond Lengths of Ethyne, Ethene, and Ethane |
| 1.15 | 35 | A Summary of Important Concepts that Come from Quantum Mechanics |
| 1.16 | 36 | Molecular Geometry: The Valence Shell Electron-Pair Repulsion (VSEPR) Model. |
| 1.16A-F | 37 | Molecular Geometry: VSEPR Models for Methane, Ammonia, Water, Boron Trifluoride, Beryllium Hydride and Carbon Dioxide |
| 1.17 | 39 | Representation of Structural Formulas: Dash; Condensed; Bond Line; and the Three Dimensional Wedge, Dash, Line Representation |
| 1.18 | 44 | Applications of Basic Principles: Opposite Charges Attract; Like Charges repel; Nature Tends Towards States of Lower Potential Energy; Orbital Overlap Stabilizes Molecules |
| | 45 | Key Terms and Concepts |
| | 46 | Concept Map |

Practice Problems: You are encouraged to work all of the in-chapter problems, and you are required to complete the short in-class weekly assignments. Routinely doing problems in organic chemistry leads to understanding of the theory, and good grades in organic chemistry.

In the words of Solomons and Fryhle:

“One way to check your progress is to work each of the in-chapter problems when you come to it. These problems have been written just for this purpose and are designed to help you decide whether or not you understand the material that has just been explained.”

And, in the words of Wade:

“It’s easy to fool yourself into thinking you understand organic chemistry when you actually do not. As you read through this book, all the facts and ideas may make sense, yet you have not learned to combine and use those facts and ideas. An examination is a painful time to learn that you do not really understand the material.

The best way to understand organic chemistry is to use it. You will certainly need to read and reread all the material in the chapter, but this level of understanding is just the beginning. Problems are provided so you can work with the ideas, applying them to new compounds and new reactions that you have never seen before. By working problems, you force yourself to use the material and fill in the gaps in your understanding. You also increase your level of self-confidence and your ability to do well on exams”.

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| Problems: | In-Chapter | 1.1 to 1.15 |
| 47 | End of Chapter | 1.16 to 1.38 |
| 50 | Learning Group Problem | |

Week of Jan 19: REPRESENTATIVE CARBON COMPOUNDS: Functional Groups, Intermolecular Forces, and Infrared (IR) Spectroscopy

| | | |
|-------|----|---|
| | | Read and Study Chapter 2 |
| | 51 | Structure and Function: Organic Chemistry, Nanotechnology, and Bioengineering |
| 2.1 | 52 | Carbon-Carbon Covalent Bonds |
| 2.2 | 52 | Hydrocarbons: Representative, Alkanes, Alkenes, Alkynes, and Aromatic Compounds |
| 2.3 | 55 | Polar Covalent Bonds |
| 2.4 | 56 | Polar and Nonpolar Molecules |
| 2.4A | 58 | Dipole Moments in Alkenes |
| 2.5 | 59 | Functional Groups |
| 2.5A | 59 | Alkyl Groups and the Symbol R |
| 2.5B | 60 | Phenyl and Benzyl Groups |
| 2.6 | 60 | Alkyl Halides or Haloalkanes |
| 2.7 | 61 | Alcohols, including Classification as Primary, Secondary and Tertiary (1E, 2E, 3E) |
| 2.8 | 63 | Ethers |
| 2.9 | 63 | Amines, including Classification as Primary, Secondary and Tertiary |
| 2.10 | 65 | Aldehydes and Ketones |
| 2.11 | 65 | Carboxylic Acids, Esters, and Amides |
| 2.12 | 67 | Nitriles |
| 2.13 | 68 | Summary of Important Families of Organic Compounds |
| 2.14 | 68 | Physical Properties and Molecular Structure with emphasis on Intermolecular Interactions, namely: |
| 2.14A | 69 | Ion-Ion Forces in ionic compounds, e.g. sodium acetate, sodium chloride |
| 2.14B | 70 | Dipole-Dipole Forces resulting from permanent dipoles, e.g. acetone, chloromethane |

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| 2.14C | 70 | Hydrogen Bonds |
| 2.14D | 71 | van der Waals Forces, or London forces or dispersion forces, e.g. methane |
| 2.14E | 73 | Solubilities |
| 2.14F | 74 | Guidelines for Water Solubility |
| 2.14G | 74 | Intermolecular Forces in Biochemistry, and Organic Templates Engineered to Mimic Bone Growth |
| 2.15 | 75 | Summary of Attractive Electric Forces |
| 2.16 | 76 | Infrared Spectroscopy: An Instrumental Method for Detecting Functional Groups |
| 2.16A | 80 | Infrared Spectra of Hydrocarbons |
| 2.16B | 82 | IR Spectra of Some Functional Groups Containing Heteroatoms including Carbonyl Functional Groups of Aldehydes, Ketones, Esters, Carboxylic Acids and Amides, plus Alcohols, Phenols and Amines |
| 2.17 | 84 | Applications of Basic principles: Polar Bonds are Caused by Electronegativity Differences; Opposite Charges Attract; Molecular Structure Determines Properties |
| | 85 | Key Terms and Concepts |
| | 86 | Concept Map |
| Problems: | In-Chapter | 2.1 to 2.19 |
| | 87 | End of Chapter 2.20 to 2.48 |
| | 90 | Learning Group Problem |

**Week of Jan 26: AN INTRODUCTION TO ORGANIC REACTIONS:
ACIDS AND BASES IN ORGANIC CHEMISTRY**

| | | |
|------|-----|--|
| | | Read and Study Chapter 3 |
| | 91 | Diamox, a drug that prevents altitude sickness |
| | 91 | Shuttling the Protons, or, from the Lewis and Sloan perspective, Shuttling the Electrons |
| 3.1 | 92 | Reactions and their Mechanisms - Substitution, Addition, Elimination and Rearrangement Reactions |
| 3.1A | 92 | Homolysis and Heterolysis of Covalent Bonds, and Introduction to the Use of Curved Arrows |
| 3.2 | 94 | Acids and Bases |
| 3.2A | 94 | The Brønsted-Lowry Definition of Acids and Bases |
| 3.2B | 95 | The Lewis Definition of Acids and Bases |
| 3.2C | 96 | Opposite Charges Attract |
| | 97 | The Chemistry of ... HOMOs and LUMOs in Reactions |
| 3.3 | 97 | Heterolysis of Bonds to Carbon - Carbocations and Carbanions |
| 3.4 | 98 | The Use of Curved Arrows in Illustrating Reactions |
| 3.5 | 100 | The Strength of Acids and Bases, K_a and pK_a |
| 3.5A | 100 | The Acidity Constant, K_a |
| 3.5B | 100 | Acidity and pK_a |
| | 101 | Table 3.1: Relative Strength of Selected Acids and Their Conjugate Bases |
| 3.5C | 102 | Predicting the Strength of Bases the Stronger the Acid, the Weaker the Conjugate Base |
| 3.6 | 103 | Predicting the Outcome of Acid-Base Reactions |
| 3.6A | 104 | Water Solubility as a Result of Salt Formation |
| 3.7 | 105 | The Relationship between Structure and Acidity, i.e. Structural Effects on Acidity and Basicity, namely: |

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| | 1. | Size Effect, acidity increases upon descending a column in the Periodic Table, H-I is a stronger acid than H-F; the acidity order is: H-I > H-Br > H-Cl > H-F |
| | 2. | Electronegativity Effect, acidity increases from left to right in the Periodic Table, H-F is a stronger acid than CH ₄ ; the acidity order is: HF > H ₂ O > NH ₃ > CH ₄ |
| 3.7A | 107 | 3. The Effect of Hybridization, more s-character means the anion has lower energy, is more stable, and is a weaker base |
| 3.7B | 108 | 4. Inductive Effects, from polarization by electron attracting and electron withdrawing groups |
| 3.8 | 108 | Energy Changes; higher potential and kinetic energy implies less stable, lower energy implies more stable |
| 3.8A | 109 | Potential Energy and Covalent Bonds, exothermic reactions give out heat, endothermic reactions absorb heat |
| 3.9 | 110 | The Relationship Between the Equilibrium Constant and the Standard Free-Energy Change, ΔG° ; a negative value favours products at equilibrium |
| 3.10 | 111 | The Acidity of Carboxylic Acids, with explanations arising from Resonance Effects and Inductive Effects |
| 3.10A | 112 | The Effect of Delocalization: An Explanation based on Resonance Effects, due to resonance stabilization of the carboxylate anion |
| 3.10B | 113 | An Explanation based on Inductive Effects, due to inductive withdrawal of electronic charge by -O and -C=O in carboxylate anions |
| 3.10C | 114 | Summary of a Comparison of Conjugate Acid-Base Strengths |
| 3.10D | 114 | Inductive Effects of Other Groups |
| 3.11 | 115 | The Effect of Solvent on Acidity - Protic Solvents |
| 3.12 | 116 | Organic Compounds as Bases |
| 3.13 | 117 | A Mechanism for an Organic Reaction |
| | 118 | The Chemistry of carbonic Anhydrase |
| 3.14 | 119 | Acid and Base in Nonaqueous Solutions |
| 3.15 | 120 | Acid-Base Reactions, and Synthesis of Deuterium- and Tritium-Labelled Compounds |
| 3.16 | 121 | Applications of Basic Principles: Electronegativity Differences Polarize Bonds; Polarized Bonds Underlie Inductive Effects; Opposite Charges Attract; Nature Prefers States of Lower Potential Energy; Resonance Effects Can Stabilize Molecules and Ions |
| | 122 | Key Terms and Concepts |
| | 123 | Concept Map |
| Problems: | In-Chapter | 3.1 to 3.14 |
| | 124 | End of Chapter 3.15 to 3.42 |
| | 127 | Learning Group Problem |

Week of Feb 2: NOMENCLATURE AND CONFORMATIONS OF ALKANES AND CYCLOALKANES

Read and Study Chapter 4

| | | |
|------|-----|---|
| | 129 | To be Flexible or Inflexible - Molecular Structure Makes the Difference |
| 4.1 | 130 | Introduction to Alkanes and Cycloalkanes |
| 4.1A | 130 | Sources of Alkanes: Petroleum |
| | 130 | The Chemistry of Petroleum Refining |
| | 131 | Typical Fractions Obtained by Distillation of Petroleum |

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| 4.2 | 132 | Shapes of Alkanes |
| | 133 | Tables 4.1: Physical Constants of Hexane Isomers |
| | 134 | Table 4.2: Number of Alkane Isomers |
| | 135 | Table 4.3: The Unbranched Alkanes |
| 4.3 | 134 | IUPAC Nomenclature of Alkanes, Alkyl Halides and Alcohols |
| 4.3A | 135 | Nomenclature of Unbranched Alkyl Groups |
| 4.3B | 135 | Nomenclature of Branched-Chain Alkanes |
| 4.3C | 137 | Nomenclature of Branched Alkyl Groups |
| 4.3D | 138 | Classification of Hydrogen Atoms, as Primary (1°), Secondary (2°), and Tertiary (3°) |
| 4.3E | 139 | Nomenclature of Alkyl Halides |
| 4.3F | 139 | Nomenclature of Alcohols |
| 4.4 | 141 | Nomenclature of Cycloalkanes |
| 4.4A | 141 | Monocyclic Compounds |
| 4.4B | 142 | Bicyclic Compounds |
| 4.5 | 143 | Nomenclature of Alkenes and Cycloalkenes |
| 4.6 | 145 | Nomenclature of Alkynes |
| 4.7 | 146 | Physical Properties of Alkanes and Cycloalkanes |
| | 148 | The Chemistry of Pheromones: Communication by Means of Chemicals |
| 4.8 | 148 | Sigma (Φ) Bonds and Bond Rotation |
| 4.9 | 151 | Conformational Analysis of Butane |
| 4.10 | 153 | The Relative Stability of Cycloalkanes: Ring Strain |
| 4.10A | 153 | Heats of Combustion |
| 4.10B | 154 | Heats of Combustion of Cycloalkanes |
| | 154 | Table 4.5: Heats of Combustion and Ring Strain of Cycloalkanes |
| 4.11 | 155 | The origin of Ring Strain in Cyclopropane and Cyclobutane: Angle Strain and Torsional Strain |
| 4.11A | 155 | Cyclopropane |
| 4.11B | 156 | Cyclobutane |
| 4.11C | 156 | Cyclopentane |
| 4.12 | 156 | Conformations of Cyclohexane |
| 4.12A | 158 | Conformations of Higher Cycloalkanes |
| | 159 | The Chemistry of Nanoscale Motors and Molecular Switches |
| 4.13 | 160 | Substituted Cyclohexanes, Axial and Equatorial Hydrogen Atoms |
| 4.14 | 163 | Disubstituted Cyclohexanes, Cis-Trans Isomerism |
| 4.14A | 164 | Cis-Trans Isomerism and Conformational Structures |
| 4.15 | 166 | Bicyclic and Polycyclic Alkanes |
| | 167 | The Chemistry of Elemental Carbon |
| 4.16 | 168 | Chemical Reactions of Alkanes |
| 4.17 | 168 | Synthesis of Alkanes and Cycloalkanes |
| 4.17A | 168 | Hydrogenation of Alkenes and Alkynes |
| 4.18 | 169 | Structural Information from Molecular Formulas and the Index of Hydrogen Deficiency |
| 4.18A | 170 | Compounds Containing Halogens, Oxygen, or Nitrogen |
| 4.19 | 171 | ¹³ C NMR Spectroscopy- A Practical Introduction |
| 4.19A | 172 | One Signal for each Unique Carbon |
| 4.19B | 173 | Chemical Shift – Location of the Signal Depends on Electronic Environment |
| 4.19C | 174 | Using ¹³ C NMR to Elucidate Structure |
| 4.20 | 175 | Application of Basic Principles: Nature Prefers States of Lower Energy; |
| | 176 | Key Terms and Concepts |
| | 177 | Concept Maps |

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| Problems: | In-Chapter | 4.1 to 4.21 |
| | 178 | End of Chapter 4.22 to 4.54 |
| | 180 | Learning Group Problems |

Week of Feb 9: **STEREOCHEMISTRY: CHIRAL MOLECULES**

Read and Study Chapter 5

| | | |
|-------|-----|---|
| | 181 | The Handedness of Life |
| 5.1 | 182 | The Biological Significance of Chirality |
| 5.2 | 183 | Isomerism, Constitutional Isomers and Stereoisomers |
| 5.3 | 184 | Enantiomers and Chiral Molecules |
| 5.4 | 187 | More about the Biological Importance of Chirality |
| 5.5 | 188 | The Historical Origin of Stereochemistry |
| 5.6 | 189 | Tests for Chirality, Planes of Symmetry and Points of Symmetry |
| 5.7 | 190 | Nomenclature of Enantiomers: The R-S System |
| 5.8 | 194 | Properties of Enantiomers, Optical Activity |
| 5.8A | 195 | Plane-Polarized Light |
| 5.8B | 195 | The Polarimeter |
| 5.8C | 195 | Specific Rotation |
| 5.9 | 198 | The Origin of Optical Activity |
| 5.9A | 199 | Racemic Forms |
| 5.9B | 199 | Racemic Forms and Enantiomeric Excess |
| 5.10 | 200 | The Synthesis of Chiral Molecules |
| 5.10A | 200 | Racemic Forms |
| 5.10B | 201 | Stereoselective Synthesis |
| 5.11 | 202 | Chiral Drugs |
| | 203 | The Chemistry of: Selective Binding of Drug Enantiomers to Left- and Right-Hand Coiled DNA |
| 5.12 | 203 | Molecules with More Than One Chirality Centre |
| 5.12A | 205 | Meso Compounds |
| 5.12B | 206 | Naming Compounds with More than One Chirality Centre |
| 5.13 | 207 | Fischer Projection Formulas |
| 5.14 | 209 | Stereoisomerism of Cyclic Compounds |
| 5.14A | 209 | Cyclohexane Derivatives |
| 5.15 | 211 | Relating Configurations Through Reactions in Which No Bonds to the Chirality Centre are Broken |
| 5.15A | 212 | Relative and Absolute Configurations |
| 5.16 | 213 | Separation of Enantiomers: Resolution |
| 5.16A | 214 | Pasteur's Method for Separating Enantiomers |
| 5.16B | 214 | Current Methods for Resolution of Enantiomers |
| 5.17 | 214 | Compounds with Chirality Centres Other than Carbon |
| 5.18 | 215 | Chiral Molecules that do not Possess a Chirality Centre (a Tetrahedral Atom with Four Different Groups Attached) |
| | 216 | Key Terms and Concepts |
| | 217 | Concept Map |

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| Problems: | In-Chapter | 5.1 to 5.29 |
|-----------|------------|-------------|

- 218 End of Chapter 5.30 to 5.44
 220 Learning Group Problems
 Additional Problems - The CD accompanying the text book includes a set of computer molecular model stereochemistry exercises that are keyed to the text

Week of Feb 16: Family Day & Winter Semester Break: No Classes

Weeks of Feb 23 & March 2: IONIC REACTIONS: Nucleophilic Substitution and Elimination Reactions of Alkyl Halides

Read and Study Chapter 6

- 221 Breaking Bacteria Cell Walls With Organic Chemistry
 6.1 222 Organic Halides
 222 Table 6.1: Carbon-Halogen Bond lengths and Bond Strengths
 6.1A 223 Physical Properties of Organic Halides
 223 Table 6.2: Organic Halides
 6.2 224 Nucleophilic Substitution Reactions
 6.3 224 Nucleophiles
 6.4 225 Leaving Groups
 6.5 226 Kinetics of a Nucleophilic Substitution Reaction -
 a Substitution Nucleophilic Bimolecular (S_N2) Reaction
 6.6 227 A Mechanism for the S_N2 Reaction
 6.7 228 Transition State Theory: Free-Energy Diagrams
 6.8 229 The Stereochemistry of S_N2 Reactions
 6.9 235 The Reaction of Tert-Butyl Chloride with Hydroxide Ion: An S_N1 Reaction
 6.9A 235 Multistep Reactions and the Rate-Determining Step
 6.10 236 A Mechanism for the S_N1 Reaction
 6.11 237 Carbocations
 6.11A 237 The Structure of Carbocations
 6.11B 238 The Relative Stabilities of Carbocations
 6.12 239 The Stereochemistry of S_N1 Reactions
 6.12A 239 Reactions That Involve Racemization
 6.12B 240 Solvolysis – Cleavage of the Solvent by the Nucleophile
 6.13 241 Factor's Affecting the Rates of S_N1 and S_N2 Reactions
 6.13A 241 The Effect of the Structure of the Substrate
 241 Table 6.4: Relative Rates of Reactions of Alkyl Halides in S_N2 Reactions
 243 S_N1 Reactions and the Hammond-Leffler Postulate
 6.13B 244 The Effect of the Concentration and the Strength of the Nucleophile
 244 Nucleophilicity versus Basicity
 6.13C 245 Solvent Effects on S_N2 Reactions: Polar Protic and Aprotic Solvents
 6.13D 247 Solvent Effects on S_N1 Reactions: The Ionizing Ability of the Solvent
 247 Table 6.5: Dielectric Constants of Common Solvents
 6.13E 247 The Nature of the Leaving Group
 249 Summary of S_N1 versus S_N2
 249 Table 6.6: Factors Favouring S_N1 versus S_N2 Reactions
 6.14 250 Organic Synthesis - Functional Group Transformations Using S_N2 Reactions
 251 The Chemistry of ... Biological Methylation: A Biological Nucleophilic Substitution
 Reaction
 6.14A 252 The Unreactivity of Vinylic and Phenyl Halides

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| 6.15 | 253 | Elimination Reactions of Alkyl Halides |
| 6.15A | 253 | Dehydrohalogenation (loss of H-X) |
| 6.15B | 254 | Bases Used in Dehydrohalogenation |
| 6.15C | 255 | Mechanisms of Dehydrohalogenation: E2 and E1 Mechanisms |
| 6.16 | 255 | The Elimination-Bimolecular (E2) Reaction |
| 6.17 | 256 | The Elimination-Unimolecular (E1) Reaction |
| 6.18 | 257 | Substitution versus Elimination |
| 6.18A | 257 | S _N 2 versus E2 |
| 6.18B | 259 | Tertiary Halides: S _N 1 versus E1 |
| 6.19 | 260 | Overall Summary |
| | 260 | Table 6.7: Overall Summary of S _N 1, S _N 2, E1 and E2 Reactions |
| | 261 | Summary and Review Tools |
| | 262 | Key Terms and Concepts |
| Problems: | In-Chapter | 6.1 to 6.12 |
| | 252 | End of Chapter 6.13 to 6.48 |
| | 268 | Learning Group Problems |

**Week of March 9: ALKENES AND ALKYNES I: Properties and Synthesis.
Elimination Reactions of Alkyl Halides**

Read and Study Chapter 7

| | | |
|------|-----|---|
| | 269 | Cell Membrane Fluidity |
| 7.1 | 270 | Introduction |
| 7.1A | 270 | Physical Properties of Alkenes and Alkynes |
| 7.2 | 270 | The (E) - (Z) System for Designating Alkene Diastereomers |
| 7.3 | 272 | Relative Stabilities of Alkenes |
| 7.3A | 272 | Heat of Reaction |
| | 272 | Figure 7.2: Order of Stability of Alkenes from Heats of Hydrogenation |
| 7.3B | 273 | Overall Relative Stabilities of Alkenes |
| 7.4 | 274 | Cycloalkenes |
| 7.5 | 274 | Synthesis of Alkenes via Elimination Reactions |
| 7.6 | 275 | Dehydrohalogenation of Alkyl Halides |
| 7.6A | 275 | Zaitsev's Rule: Formation of the Most Substituted Alkene is Favoured with a Small Base |
| 7.6B | 277 | Formation of the Less Substituted Alkene Using a Bulky Base |
| 7.6C | 278 | The Stereochemistry of E2 Reactions: The Orientation of Groups in the Transition State |
| 7.7 | 280 | Acid-Catalyzed Dehydration of Alcohols |
| 7.7A | 281 | Mechanism for Dehydration of Secondary and Tertiary Alcohols: An E1 Reaction |
| 7.7B | 282 | Carbocation Stability and the Transition State |
| 7.7C | 284 | A Mechanism for Dehydration of Primary Alcohols: An E2 Reaction |
| 7.8 | 285 | Carbocation Stability and the Occurrence of Molecular Rearrangements |
| 7.8A | 285 | Rearrangements During Dehydration of Secondary Alcohols |
| 7.8B | 287 | Rearrangement after Dehydration of a Primary Alcohol |
| 7.9 | 288 | Synthesis of Alkynes by Elimination Reactions: Dehydrohalogenation of vic-Dibromides |
| 7.10 | 290 | The Acidity of Terminal Alkynes |
| 7.11 | 290 | Replacement of the Acetylenic Hydrogen Atom of Terminal Alkynes |

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| 7.12 | 292 | Alkylation of Alkynide Anions: Some General Principles of Structure and Reactivity Illustrated |
| 7.13 | 292 | Hydrogenation of Alkenes |
| | 293 | The Chemistry of Hydrogenation in the Food Industry |
| 7.14 | 294 | Hydrogenation: The Function of the Catalyst |
| 7.14A | 295 | Syn and Anti Additions |
| | 295 | The Chemistry of Homogeneous Asymmetric Catalytic Hydrogenation: Examples Involving L-DOPA, (S)-Naproxen, and Aspartame |
| 7.15 | 297 | Hydrogenation of Alkynes |
| 7.15A | 297 | Syn Addition of Hydrogen: Synthesis of cis-Alkenes |
| 7.15B | 297 | Anti Addition of Hydrogen: Synthesis of trans-Alkenes |
| 7.16 | 298 | An Introduction to organic Synthesis |
| 7.16A | 298 | Why do Organic Synthesis? |
| 7.16B | 299 | Retrosynthetic Analysis – Planning an Organic Synthesis |
| 7.16C | 300 | Identifying Precursors |
| | 302 | The Chemistry of – From the Inorganic to the Organic |
| 7.16D | 302 | Raison d’Etre |
| | 303 | Summary and Review Tools |
| | 304 | Summary of Methods for the Preparation of Alkenes and Alkynes ; |
| | | 1. Dehydrohalogenation of Alkyl Halides (Section 7.6, p 275) |
| | | 2. Dehydration of Alcohols (Sections 7.7 & 7.8, p 280) |
| | | 3. Hydrogenation of Alkynes (Section 7.15, p 297) |
| | | (4. Dehydrohalogenation of vic-Dihalides x 2 (Section 7.9, p 288)) |
| | 305 | Summary and Review Tools |
| | 306 | Key Terms and Concepts |
| Problems: | In-Chapter | 7.1 to 7.17 |
| | 306 | End of Chapter 7.18 to 7.46 |
| | 310 | Learning Group Problems |

Week of March 16: ALKENES AND ALKYNES II: Addition Reactions.

Read and Study Chapter 8.

| | | |
|------|-----|---|
| | 311 | The Sea: A Treasure of Biologically Active Natural Products |
| 8.1 | 312 | Introduction: Addition to Alkenes |
| 8.1A | 313 | Understanding Additions to Alkenes |
| 8.2 | 314 | Electrophilic Addition of Hydrogen Halides to Alkenes: Mechanism and Markovnikov’s Rule |
| 8.2A | 316 | Theoretical Explanation of Markovnikov’s Rule |
| 8.2B | 318 | Modern Statement of Markovnikov’s Rule |
| 8.2C | 319 | Regioselective Reactions |
| 8.2D | 319 | An Exception to Markovnikov’s Rule |
| 8.3 | 319 | Stereochemistry of the Ionic Addition to an Alkene |
| 8.4 | 320 | Addition of Sulfuric Acid to Alkenes |
| 8.4A | 320 | Alcohols from Alkyl Hydrogen Sulfates |
| 8.5 | 321 | Addition of Water to Alkenes: Acid Catalyzed Hydration |
| 8.5A | 321 | Mechanism for Acid-Catalyzed Hydration |
| 8.5B | 322 | Rearrangements |

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| 8.6 | 323 | Alcohols from Alkenes through Oxymercuration-Demercuration: Markovnikov Addition |
| 8.6A | 323 | Regioselectivity of Oxymercuration-Demercuration |
| 8.6B | 324 | Rearrangements Seldom Occur in Oxymercuration-Demercuration |
| 8.6C | 324 | Mechanisms of Oxymercuration |
| 8.7 | 326 | Alcohols from Alkenes through Hydroboration-Oxidation: Anti-Markovnikov Syn Hydration |
| 8.8 | 326 | Hydroboration: Synthesis of Alkylboranes |
| 8.8A | 327 | Mechanism of Hydroboration |
| 8.8B | 328 | Stereochemistry of Hydroboration |
| 8.9 | 329 | Oxidation and Hydrolysis of Alkyl Boranes |
| 8.9A | 330 | Regiochemistry and Stereochemistry of Alkyl Boranes: Oxidation and Hydrolysis |
| 8.10 | 331 | Summary of Alkene Hydration Methods |
| 8.11 | 331 | Protonolysis of Alkyl Boranes |
| 8.12 | 332 | Addition of Bromine and Chlorine to Alkenes |
| 8.12A | 333 | Mechanism of Halogen Addition |
| 8.13 | 334 | Stereochemistry of the Addition of Halogens to Alkenes |
| 8.13A | 335 | Stereospecific Reactions |
| 8.14 | 337 | Halohydrin Formation |
| 8.15 | 338 | Divalent Carbon Compounds: Carbenes |
| 8.15A | 339 | Structure and Reactions of Methylene |
| 8.15B | 339 | Reactions of Other Carbenes: Dihalocarbenes |
| 8.15C | 340 | Carbenoids: The Simmons-Smith Cyclopropane Synthesis |
| 8.16 | 340 | Oxidation of Alkenes: Syn 1,2-Dihydroxylation |
| 8.16A | 341 | Mechanisms for Syn Dihydroxylations of Alkenes |
| | 342 | The Chemistry of Catalytic Asymmetric Dihydroxylations |
| 8.17 | 343 | Oxidative Cleavage of Alkenes |
| 8.17A | 343 | Cleavage with Hot Basic Potassium Permanganate |
| 8.17B | 344 | Cleavage with Ozone |
| 8.18 | 345 | Addition of Bromine and Chlorine to Alkynes |
| 8.19 | 346 | Addition of Hydrogen Halides to Alkynes |
| 8.20 | 347 | Oxidative Cleavage of Alkynes |
| 8.21 | 347 | Synthetic Strategies Revisited, including: |
| | | 1. Construction of the Carbon Skeleton |
| | | 2. Functional Group Interconversions |
| | | 3. Control of Regiochemistry and |
| | | 4. Control of Stereochemistry |
| 8.21A | 347 | Retroactive Analysis |
| 8.21B | 348 | Disconnections, Synthons, and Synthetic Equivalents |
| 8.21C | 349 | Stereochemical Considerations |
| | 350 | The Chemistry of Cholesterol Biosynthesis: Elegant and Familiar Reactions in Nature |
| | 354 | Summary and Review Tools: |
| | 354 | Mechanism Review: Summary of Alkene Addition Reactions |
| | 355 | Synthetic Connections of Alkynes and Alkenes: II |
| | 356 | Key Terms and Concepts |
| Problems: | In-Chapter | 8.1 to 8.26 |
| | 356 | End of Chapter 8.27 to 8.68 |
| | 361 | Learning Group Problems. |

Week of March 23: RADICAL REACTIONS

Read and Study Chapter 10

| | | |
|-----------|------------|---|
| | 427 | Radicals in Biology, Medicine, and Industry |
| 10.1 | 428 | Introduction |
| 10.1A | 428 | Production of Radicals |
| 10.1B | 428 | Reactions of Radicals |
| 10.2 | 429 | Homolytic Bond Dissociation Energies |
| 10.2A | 430 | Homolytic Bond Dissociation Energies and Heats of Reaction |
| | 430 | Table 10.1 Single-Bond Homolytic Dissociation Energies DH° at 25° C |
| 10.2B | 431 | Homolytic Bond Dissociation Energies and the Relative Stabilities of Radicals |
| 10.3 | 433 | The Reactions of Alkanes with Halogens |
| 10.3A | 433 | Multiple Substitution Reactions versus Selectivity |
| 10.4 | 435 | Chlorination of Methane: Mechanism of Reaction |
| | | 1. Chain Initiation |
| | | 2. Chain Propagation |
| | | 3. Chain Termination |
| 10.5 | 437 | Chlorination of Methane: Energy Changes |
| 10.5A | 438 | The Overall Free-Energy Change |
| 10.5B | 439 | Activation Energies |
| 10.5C | 441 | Reaction of Methane with other Halogens |
| 10.6 | 443 | Halogenation of Higher Alkanes |
| 10.6A | 445 | Selectivity of Bromine, and Selectivity versus Reactivity |
| 10.7 | 446 | The Geometry of Alkyl Radicals |
| 10.8 | 446 | Reactions that Generate Tetrahedral Chirality Centres |
| 10.8A | 447 | Generation of a Second Chirality Centre in a Radical Halogenation |
| 10.9 | 449 | Radical Addition to Alkenes: |
| | | The Anti-Markovnikov Addition of Hydrogen Bromide |
| 10.9A | 450 | Summary of Markovnikov versus Anti-Markovnikov Addition of HBr to Alkenes |
| 10.10 | 451 | Radical Polymerization of Alkenes: Chain Growth Polymers |
| | 451 | Radical Polymerization of Ethene |
| | 453 | Other Common Chain-Growth Polymers |
| 10.11 | 455 | Other Important Radical Reactions |
| 10.11A | 455 | Molecular Oxygen and Super Oxide |
| 10.11B | 455 | Nitric Oxide |
| 10.11C | 456 | Combustion of Alkanes |
| 10.11D | 457 | Autoxidation |
| | 458 | The Chemistry of Antioxidants |
| | 459 | The Chemistry of Ozone Depletion and Chlorofluorocarbons (CFCs) |
| | 460 | Concept Map: Mechanism Review of Radical Reactions |
| | 461 | Key Terms and Concepts |
| | 464 | Special Topic A: Chain-Growth Polymers |
| Problems: | In-Chapter | 10.1 to 10.22 |
| | 461 | End of Chapter 10.23 to 10.34 |
| | 463 | Learning Group Problems. |

Week of March 30: ALCOHOLS AND ETHERS.

Read and Study Chapter 11.

| | | |
|---------|-----|---|
| | 469 | Molecular Hosts |
| 11.1 | 470 | Structure and Nomenclature |
| 11.1A | 471 | Nomenclature of Alcohols |
| 11.1B | 472 | Nomenclature of Ethers |
| 11.2 | 472 | Physical Properties of Alcohols and Ethers |
| | 473 | Tables 11.1 and 11.2: Physical Properties of Ethers and Alcohols |
| 11.3 | 474 | Important Alcohols and Ethers |
| 11.3A-D | 474 | Methanol, Ethanol, Ethylene Glycol, Diethyl Ether |
| 11.4 | 476 | Synthesis of Alcohols from Alkenes |
| | 476 | 1. Acid-Catalyzed Hydration of Alkenes |
| | 477 | 2. Oxymercuration-Demercuration |
| | 477 | 3. Hydroboration-Oxidation |
| 11.5 | 478 | Reactions of Alcohols |
| 11.6 | 479 | Alcohols as Acids |
| 11.7 | 480 | Conversion of Alcohols into Alkyl Halides |
| 11.8 | 480 | Alkyl Halides from the Reactions of Alcohols with Hydrogen Halides |
| 11.8A | 481 | Mechanisms of the Reactions of Alcohols with HX |
| 11.9 | 483 | Alkyl Halides from the Reactions of Alcohols with PBr_3 or SOCl_2 |
| 11.10 | 484 | Tosylates, Mesylates and Triflates: Leaving Group Derivatives of Alcohols |
| | 487 | The Chemistry of Alkyl Phosphates |
| 11.11 | 487 | Synthesis of Ethers |
| 11.11A | 487 | Ethers by Intermolecular Dehydration of Alcohols |
| 11.11B | 489 | The Williamson Synthesis of Ethers |
| 11.11C | 490 | Synthesis of Ethers by Alkoxymercuration-Demercuration |
| 11.11D | 490 | tert-Butyl Ethers by Alkylation of Alcohols: Protecting Groups |
| 11.11E | 491 | Silyl Ether Protecting Groups |
| 11.12 | 482 | Reactions of Ethers: Ether Cleavage by Strong Acids |
| 11.13 | 493 | Epoxides |
| 11.13A | 493 | Synthesis of Epoxides: Epoxidation of Alkenes |
| 11.13B | 495 | Stereochemistry of Epoxidation |
| | 494 | The Chemistry of The Sharpless Asymmetric Epoxidation |
| 11.14 | 496 | Reactions of Epoxides: |
| | | 1. Acid Catalyzed Ring Opening |
| | | 2. Base Catalyzed Ring Opening |
| | 498 | The Chemistry of Epoxides, Carcinogens, and Biological Oxidation |
| 11.14A | 499 | Polyethers from Epoxides |
| 11.15 | 500 | Anti 1,2-Dihydroxylation of Alkenes via Epoxides |
| | 502 | The Chemistry of Environmentally Friendly Alkene Oxidation Methods |
| 11.16 | 503 | Crown Ethers: Nucleophilic Substitution Reactions in Relatively Nonpolar Aprotic Solvents by Phase-Transfer Catalysis |
| 11.16A | 504 | Crown Ethers |
| 11.16B | 506 | Transport Antibiotics and Crown Ethers |
| 11.17 | 506 | Summary of Reactions of Alkenes, Alcohols and Ethers |

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| 11.17A | 506 | Alkenes in Synthesis |
| | 507 | Key Terms and Concepts. |
| | 508 | Summary and Review Tool: Some Synthetic Connections of Alkynes, Alcohols, Alkyl Halides and Ethers |
| Problems: | In-Chapter | 11.1 to 11.24 |
| | 509 | End of Chapter 11.25 to 11.51 |
| | 512 | Learning Group Problems. |

Week of April 6: ALCOHOLS FROM CARBONYL COMPOUNDS: OXIDATION-REDUCTION AND ORGANOMETALLIC COMPOUNDS.

| | | |
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| | | Read and Study Chapter 12 |
| | 513 | The Two Aspects of the Coenzyme NADH |
| 12.1 | 514 | Introduction |
| 12.1A | 514 | Structure of the Carbonyl Group |
| 12.1B | 515 | Reactions of Carbonyl Compounds with Nucleophiles |
| 12.2 | 515 | Oxidation-Reduction Reactions in Organic Chemistry |
| 12.2A | 516 | Oxidation States of Organic Chemistry |
| 12.3 | 517 | Alcohols by Reduction of Carbonyl Compounds |
| 12.3A | 517 | Lithium Aluminum Hydride Reductions of Carbonyl Compounds |
| 12.3B | 518 | Sodium Borohydride Reductions of Carbonyl Compounds |
| 12.3C | 519 | Overall Summary of LiAlH_4 and NaBH_4 Reactivity |
| | 519 | The Chemistry of Alcohol Dehydrogenase |
| | 520 | The Chemistry of Stereoselective Reductions of Carbonyl Groups |
| 12.4 | 521 | Oxidation of Alcohols |
| 12.4A | 521 | Oxidation of Primary Alcohols to Aldehydes: RCH_2OH to RCHO |
| 12.4B | 522 | Oxidation of Primary Alcohols to Carboxylic Acids: RCH_2OH to RCO_2H |
| 12.4C | 522 | Oxidation of Secondary Alcohols to Ketones: $\text{RCH}(\text{OH})\text{R}'$ to RCOR' |
| 12.4D | 523 | Mechanism of Chromate Oxidations |
| 12.4E | 525 | A Chemical Test for Primary and Secondary Alcohols |
| 12.4F | 525 | Spectroscopic Evidence for Alcohols |
| 12.5 | 526 | Organometallic Compounds |
| 12.6 | 526 | Preparation of Organo Lithium and Organo Magnesium Compounds |
| 12.6A | 526 | Organolithium Compounds |
| 12.6B | 527 | Grignard Reagents |
| 12.7 | 528 | Reactions of Organolithium and Organomagnesium Compounds |
| 12.7A | 528 | Reactions with Compounds Containing Acidic Hydrogen Atoms |
| 12.7B | 529 | Reactions of Grignard Reagents with Oxiranes (Epoxides) |
| 12.7C | 530 | Reactions of Grignard Reagents with Carbonyl Compounds |
| 12.8 | 531 | Alcohols from Grignard Reagents: Reaction of Grignard Reagents with: |
| | | 1. Formaldehyde to Give Primary Alcohols |
| | | 2. Other Aldehydes to Give Secondary Alcohols |
| | | 3. Ketones to Give Tertiary Alcohols |
| | | 4. Esters with $2 \times \text{RMgX}$ to Give Tertiary Alcohols |
| 12.8A | 532 | Planning a Grignard Synthesis |
| 12.8B | 536 | Restrictions on the Use of Grignard Reagents |
| 12.8C | 537 | The Use of Lithium Reagents |
| 12.8D | 537 | The Use of Sodium Alkynides |
| 12.9 | 539 | Protecting Groups |

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| 540 | Summary of Reactions |
| 541 | Synthetic Connections of Alcohols and Carbonyl Compounds |
| 541 | Key Terms and Concepts |

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| Problems: | In-Chapter | 12.1 to 12.10 |
| 542 | End of Chapter | 12.11 to 12.29 |
| 545 | Learning Group Problems. | |
| 546 | First Review Problem Set 1 to 25. | |

Week of April 13: CONJUGATED UNSATURATED SYSTEMS.

Read and Study Chapter 13.

| | |
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| 550 | Molecules With the Nobel Prize in Their Synthetic Lineage |
| 13.1 | 551 Introduction |
| 13.2 | 551 Allylic Substitution and the Allyl Radical |
| 13.2A | 552 Allylic Chlorination (High Temperature) |
| 13.2B | 554 Allylic Bromination with N-Bromosuccinimide (Low Conc. of Br ₂) |
| 13.3 | 555 The Stability of the Allyl Radical |
| 13.3A | 555 Molecular Orbital Description of the Allyl Radical |
| 13.3B | 557 Resonance Description of the Allyl radical |
| 13.4 | 558 The Allyl Carbocation |
| 13.5 | 559 Summary of Rules for Resonance |
| 13.5A | 560 Rules for Writing Resonance Structures |
| 13.5B | 561 Estimating the Relative Stability of Resonance Structures |
| 13.6 | 563 Alkadienes and Polyunsaturated Hydrocarbons |
| 13.7 | 564 1,3-Butadiene: Electron Delocalization |
| 13.7A | 564 Bond Lengths of 1,3-Butadiene |
| 13.7B | 565 Conformations of 1,3-Butadiene, s-cis and s-trans |
| 13.7C | 565 Molecular Orbitals of 1,3-Butadiene |
| 13.8 | 566 The Stability of Conjugated Dienes |
| 13.9 | 568 Ultraviolet-Visible Spectroscopy |
| 13.9A | 568 The Electromagnetic Spectrum |
| 13.9B | 569 UV-Vis Spectrophotometers |
| 13.9C | 571 Absorption Maxima for Nonconjugated and Conjugated Dienes |
| | 573 The Chemistry of The Photochemistry of Vision |
| 13.9D | 576 Analytical Uses of UV-Vis Spectroscopy |
| 13.10 | 576 Electrophilic Attack on Conjugated Dienes: 1,4-Electrophilic Addition |
| 13.10A | 578 Kinetic Control versus Thermodynamic Control of a Chemical Reaction |
| 13.11 | 580 The Diels-Alder Reaction: 1,4-Cycloaddition of Dienes |
| 13.11A | 581 Factors Favoring the Diels-Alder Reaction |
| 13.11B | 582 Stereochemistry of the Diels-Alder Reaction |
| 13.11C | 584 Molecular Orbital Considerations That Favor an Endo Transition State |
| | 586 The Chemistry of Asymmetric and Intramolecular Diels-Alder Reactions |
| | 588 Concept Map |
| | 589 Key Terms and Concepts. |

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| Problems: | In-Chapter | 13.1 to 13.15 |
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- 589 End of Chapter 13.16 to 13.46
594 Learning Group Problems.

CHEMISTRY 2610: READING, STUDYING, AND PRACTICE PROBLEMS

All references are to Wade, L.G.(Jr), *Organic Chemistry*, 6th Edition, Pearson Prentice-Hall, 2006.

FALL SEMESTER

Weeks of

**Jan 5, 12, 19 & 26: INTRODUCTION AND REVIEW, Chapter 1;
STRUCTURE AND PROPERTIES OF ORGANIC MOLECULES, Chap. 2;
INFRARED SPECTROSCOPY, Chap. 12, Sect 12-1 to 12-12;**

Chapter 1, INTRODUCTION AND REVIEW

| Sect # | Page # | Read and Study Chapter 1 |
|--------|--------|--|
| 1-1 | 1 | The origin of Organic Chemistry |
| 1-2 | 3 | Principles of Atomic Structure |
| 1-3 | 6 | Bond Formation: The Octet |
| 1-4 | 7 | Lewis Structures |
| 1-5 | 8 | Multiple Bonding |
| 1-6 | 9 | Electronegativity and Bond Polarity |
| | 9 | Summary: Common Bonding Patterns (uncharged) |
| 1-7 | 12 | Formal Charge |
| 1-8 | 12 | Ionic Structures |
| | 13 | Summary: Common Bonding Patterns in Organic Compounds and Ions |
| 1-9 | 13 | Resonance |
| 1-10 | 17 | Structural Formulas |
| 1-11 | 20 | Molecular Formulas and Empirical Formulas |
| 1-12 | 21 | Arrhenius Acids and Bases |
| 1-13 | 22 | Bronsted-Lowry Acids and Bases |
| 1-14 | 29 | Lewis Acids and Bases |
| | 32 | Chapter 1 Glossary |
| | 34 | Essential Problem Solving Skills in Chapter 1 |
| | 34 | Study Problems: |
| | | In-Chapter, 1-1 to 1-19 |
| | 34 | End of Chapter 1-20 to 1-48 |

Practice Problems: You are encouraged to work all of the in-chapter problems, and you are required to complete the short in-class weekly assignments. Routinely doing problems in organic chemistry leads to understanding of the theory, and good grades in organic chemistry.

In the words of Solomons and Fryhle:

“One way to check your progress is to work each of the in-chapter problems when you come to it. These problems have been written just for this purpose and are designed to help you decide whether or not you understand the material that has just been explained.”

And, in the words of Wade:

“It’s easy to fool yourself into thinking you understand organic chemistry when you actually do not. As you read through this book, all the facts and ideas may make sense, yet you have not learned to combine and use those facts and ideas. An examination is a painful time to learn that you do not really understand the material.

The best way to understand organic chemistry is to use it. You will certainly need to read and reread all the material in the chapter, but this level of understanding is just the beginning. Problems are provided so you can work with the ideas, applying them to new compounds and new reactions that you have never seen before. By working problems, you force yourself to use the material and fill in the gaps in your understanding. You also increase your level of self-confidence and your ability to do well on exams”.

Chapter 2, STRUCTURE AND PROPERTIES OF ORGANIC MOLECULES;

Read and Study Chapter 2

| | | |
|------|----|---|
| 2-1 | 39 | Wave Properties of Electrons in Orbitals |
| 2-2 | 41 | Molecular Orbitals |
| 2-3 | 44 | Pi Bonding |
| 2-4 | 45 | Hybridization and Molecular Shapes |
| 2-5 | 49 | Drawing Three-Dimensional Molecules |
| 2-6 | 50 | General Rules of Hybridization and Geometry |
| 2-7 | 54 | Bond Rotation |
| 2-8 | 56 | Isomerism |
| 2-9 | 58 | Polarity of Bonds and Molecules |
| 2-10 | 61 | Intermolecular Forces |
| 2-11 | 65 | Polarity Effects on Solubilities |
| 2-12 | 68 | Hydrocarbons |
| 2-13 | 71 | Organic Compounds Containing Oxygen |
| 2-14 | 73 | Organic Compounds Containing Nitrogen |
| | 75 | Chapter 2 Glossary |
| | 77 | Essential Problem Solving Skills in Chapter 2 |
| | 77 | Study Problems |
| | | In-Chapter, 2-1 to 2-22 |
| | 77 | End of Chapter 2-23 to 2-44 |

Chapter 12, Sections 12-1 to 12-12; INFRARED SPECTROSCOPY

Read and Study Chapter 12, Sections 12-1 to 12-12

| | | |
|------|-----|---|
| 12-1 | 508 | Introduction |
| 12-2 | 509 | The Electromagnetic Spectrum |
| 12-3 | 510 | The Infrared Region |
| 12-4 | 511 | Molecular Vibrations |
| 12-5 | 513 | IR-Active and IR-Inactive Vibrations |
| 12-6 | 514 | Measurement of the IR Spectrum |
| 12-7 | 517 | Infrared Spectroscopy of Hydrocarbons |
| 12-8 | 522 | Characteristic Absorptions of Alcohols and Amines |

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| 12-9 | 523 | Characteristic Absorptions of Carbonyl Compounds |
| 12-10 | 529 | Characteristic Absorptions of C-N Bonds |
| 12-11 | 530 | Simplified Summary of IR Stretching Frequencies |
| 12-12 | 532 | Reading and Interpreting IR Spectra (Solved Problems) |
| | 552 | Study Problems |
| | | In-Chapter 12-1 to 12-6 |
| | 552 | End of Chapter 12-12 to 12-28 |

Week of Feb 2: STRUCTURE AND STEREOCHEMISTRY OF ALKANES

Read and Study Chapter 3

| | | |
|------|-----|---|
| 3-1 | 81 | Classification of Hydrocarbons (Review) |
| 3-2 | 82 | Molecular Formulas of Alkanes |
| 3-3 | 83 | Nomenclature of Alkanes |
| | 83 | Summary: Rules of Naming Alkanes |
| 3-4 | 89 | Physical Properties of Alkanes |
| 3-5 | 91 | Uses and Sources of Alkanes |
| 3-6 | 93 | Reactions of Alkanes |
| 3-7 | 94 | Structure and Conformations of Alkanes |
| 3-8 | 98 | Conformations of Butane |
| 3-9 | 100 | Conformations of Higher Alkanes |
| 3-10 | 100 | Cycloalkanes |
| 3-11 | 103 | cis-trans Isomerism in Cycloalkanes |
| 3-12 | 103 | Stabilities of Cycloalkanes: Ring Strain |
| 3-13 | 107 | Cyclohexane Conformations |
| | 110 | Problem-Solving Strategy: Drawing Chair Conformations |
| 3-14 | 111 | Conformations of Monosubstituted Cyclohexanes |
| 3-15 | 114 | Conformations of Disubstituted Cyclohexanes |
| | 116 | problem-Solving Strategy: Recognizing cis and trans isomers |
| 3-16 | 117 | Bicyclic Molecules |
| | 119 | Chapter 3 Glossary |
| | 122 | Essential Problem Solving Skills in Chapter 3 |
| | 122 | Study Problems |
| | | In-Chapter, 3-1 to 3-31 |
| | 34 | End of Chapter 3-32 to 3-46 |

Week of Feb 9: STEREOCHEMISTRY: CHIRAL MOLECULES

Read and Study Chapter 5

| | | |
|-----|-----|---|
| 5-1 | 167 | Introduction |
| 5-2 | 168 | Chirality |
| 5-3 | 174 | (R) and (S) Nomenclature of Asymmetric Carbon Atoms |
| 5-4 | 179 | Optical Activity |
| 5-5 | 184 | Biological Discrimination of Enantiomers |
| 5-6 | 185 | Racemic Mixtures |
| 5-7 | 186 | Enantiomeric Excess and Optical Purity |

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| 5-8 | 187 | Chirality of Conformation of Mobile Systems |
| 5-9 | 189 | Chiral Compounds without Asymmetric Atoms |
| 5-10 | 191 | Fischer projections |
| | 197 | Summary: Fischer projections and Their Use |
| 5-11 | 196 | Diastereomers |
| | 197 | Summary: Types of isomers |
| 5-12 | 198 | Stereochemistry of Molecules with Two or More Asymmetric Carbons |
| 5-13 | 199 | Meso Compounds |
| 5-14 | 201 | Absolute and Relative Configuration |
| 5-15 | 203 | Physical properties of Diastereomers |
| 5-16 | 204 | Resolution of Enantiomers |
| | 207 | Chapter 5 Glossary |
| | 209 | Essential problem-Solving Skills in Chapter 5 |
| | 209 | Study Problems |
| | | In-Chapter, 5-1 to 5-24 |
| | 209 | End of Chapter 5-25 to 5-39 |

Week of Feb 16: Family Day & Winter Semester Break: No Classes

Weeks of Feb 23 & March 2: ALKYL HALIDES: NUCLEOPHILIC SUBSTITUTION AND ELIMINATION REACTIONS

Read and Study Chapter 6

| | | |
|------|-----|---|
| 6-1 | 212 | Introduction |
| 6-2 | 213 | Nomenclature of Alkyl Halides |
| 6-3 | 215 | Common Uses of Alkyl Halides |
| 6-4 | 217 | Structure of Alkyl Halides |
| 6-5 | 218 | Physical Properties of Alkyl Halides |
| 6-6 | 220 | Preparation of Alkyl Halides |
| | 223 | Summary: Method of preparing Alkyl halides |
| 6-7 | 225 | Reactions of Alkyl Halides: Substitution and Elimination |
| 6-8 | 226 | Second-Order Nucleophilic Substitution: S_N2 Reaction |
| | 227 | Key Mechanism: The S_N2 Reaction |
| 6-9 | 228 | Generality of the S_N2 Reaction |
| | 228 | Summary: S_N2 Reactions of Alkyl Halides |
| 6-10 | 230 | Factors Affecting S_N2 Reactions: Strength of the Nucleophile |
| | 231 | Summary: Trends in Nucleophilicity |
| 6-11 | 234 | Reactivity of the Substrate in S_N2 Reactions |
| 6-12 | 238 | Stereochemistry of the S_N2 Reaction |
| 6-13 | 240 | First-Order Nucleophilic Substitution: The S_N1 Reaction |
| | 241 | Key Mechanism: The S_N1 Reaction |
| 6-14 | 244 | Stereochemistry of the S_N1 Reaction |
| 6-15 | 246 | Rearrangements in S_N1 Reactions |
| 6-16 | 249 | Comparison of S_N1 and S_N2 Reactions |
| | 251 | Summary: Nucleophilic Substitutions |
| 6-17 | 252 | First-Order Elimination: The $E1$ Reaction |
| | 252 | Key Mechanism: The $E1$ Reaction |
| | 256 | Summary: Carbocation Reactions |
| 6-18 | 257 | Positional Orientation of Elimination: Zaitsev's Rule |

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|------|-----|---|
| 6-19 | 258 | Second-Order Elimination: The E2 Reaction |
| | 259 | Key Mechanism: The E2 Reaction |
| 6-20 | 261 | Stereochemistry of the E2 Reaction |
| 6-21 | 262 | Comparison of E1 and E2 Elimination Mechanisms |
| | 264 | Summary: Elimination Reactions |
| | 264 | Problem Solving Strategy: Predicting Substitutions and Eliminations |
| | 267 | Summary: Reactions of Alkyl Halides |
| | 270 | Chapter 6 Glossary |
| | 272 | Essential problem Solving Skills in Chapter 6 |
| | 273 | Study Problems |
| | | In-Chapter 6-1 to 6-40 |
| | 273 | End of Chapter 6-41 to 6-75 |

Week of March 9 & 16: ALKENES, AND ALKYNES: STRUCTURE, SYNTHESSES AND REACTIONS (Chapters 7, 8 and 9)

Chapter 7: STRUCTURE AND SYNTHESIS OF ALKENES

Read and Study Chapter 7

| | | |
|------|-----|--|
| 7-1 | 279 | Introduction |
| 7-2 | 280 | The Orbital Description of the Alkene Double Bond |
| 7-3 | 281 | Elements of Unsaturation |
| 7-4 | 283 | Nomenclature of Alkenes |
| 7-5 | 285 | Nomenclature of Cis-Trans Isomers |
| | 287 | Summary: Rules of Naming Alkenes |
| 7-6 | 288 | Commercial Importance of Alkenes |
| 7-7 | 290 | Stability of Alkenes |
| 7-8 | 296 | Physical Properties of Alkenes |
| 7-9 | 298 | Alkene Synthesis by Elimination of Alkyl halides |
| 7-10 | 306 | Alkene Synthesis by Dehydration of Alcohols |
| | 307 | Key Mechanism Acid Catalyzed Dehydration of an Alcohol |
| 7-11 | 309 | Alkenes Synthesis by High Temperature Industrial methods |
| | 310 | Problem Solving Strategy: Proposing Reaction mechanisms |
| | 314 | Summary: Methods of Synthesis of Alkenes |
| | 316 | Chapter 7 Glossary |
| | 317 | Essential Problem Solving Skills in Chapter 7 |
| | 318 | Study Problems |
| | | In-Chapter 7-1 to 7-29 |
| | 318 | End of Chapter 7-30 to 7-56 |

Chapter 8: REACTIONS OF ALKENES

Read and Study Chapter 8

| | | |
|-----|-----|--|
| 8-1 | 321 | Reactivity of the Carbon-Carbon Double Bond |
| 8-2 | 322 | Electrophilic Addition to Alkenes |
| | 322 | Key Mechanism: Electrophilic Addition to Alkenes |
| 8-3 | 324 | Addition of Hydrogen halides to Alkenes |

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|------|-----|---|
| 8-4 | 330 | Addition of Water: Hydration of Alkenes |
| 8-5 | 333 | Hydration by Oxymercuration-Demercuration |
| 8-6 | 335 | Alkoxymercuration-Demercuration |
| 8-7 | 336 | Hydroboration of Alkenes |
| 8-8 | 342 | Addition of Halogens to Alkenes |
| 8-9 | 345 | Formation of Halohydrins |
| 8-10 | 348 | Catalytic Hydrogenation of Alkenes |
| 8-11 | 350 | Addition of Carbenes to Alkenes |
| 8-12 | 353 | Epoxidation of Alkenes |
| 8-13 | 355 | Acid-Catalyzed opening of Epoxides |
| 8-14 | 358 | Syn Hydroxylation of Alkenes |
| 8-15 | 360 | Oxidative Cleavage of Alkenes |
| 8-16 | 363 | Polymerization of Alkenes |
| | 367 | Problem-Solving Strategy: Organic Synthesis |
| | 370 | Summary: Reactions of Alkenes |
| | 374 | Chapter 8 Glossary |
| | 376 | Essential Problem Solving Skills in Chapter 8 |
| | 376 | Study problems |
| | | In-Chapter 8-1 to 8-45 |
| | 376 | End of Chapter 8-46 to 8-72 |

Chapter 9: ALKYNES

Read and Study Chapter 9

| | | |
|------|-----|---|
| 9-1 | 382 | Introduction |
| 9-2 | 383 | Nomenclature of Alkynes |
| 9-3 | 384 | Physical Properties of Alkynes |
| 9-4 | 386 | Commercial Importance of Alkynes |
| 9-5 | 386 | Electronic Structure of Alkynes |
| 9-6 | 387 | Acidity of Alkynes: Formation of Acetylide Ions |
| 9-7 | 389 | Synthesis of Alkynes from Acetylides |
| 9-8 | 393 | Synthesis of Alkynes by Elimination Reactions |
| 9-9 | 396 | Addition Reactions of Alkynes |
| 9-10 | 406 | Oxidation of Alkynes |
| | 408 | Problem Solving Strategy: Multistep Synthesis |
| | 409 | Summary: Reactions of Alkynes |
| | 412 | Chapter 9 Glossary |
| | 413 | Essential problem-Solving Skills in Chapter 9 |
| | 413 | Study problems |
| | | In-Chapter 9-1 to 9-25 |
| | 413 | End of Chapter 9-26 to 9-43 |

**Week of March 23: THE STUDY OF CHEMICAL REACTIONS:
RADICAL REACTIONS**

Read and Study Chapter 4

| | | |
|------|-----|---|
| 4-1 | 125 | Introduction |
| 4-2 | 125 | Chlorination of Methane |
| 4-3 | 126 | The Free-Radical Chain Reaction |
| | 128 | Key mechanism: Free-Radical Halogenation |
| 4-4 | 130 | Equilibrium Constants and Free Energy |
| 4-5 | 133 | Enthalpy and Entropy |
| 4-6 | 134 | Bond-Dissociation Enthalpies |
| 4-7 | 135 | Enthalpy Changes in Chlorination |
| 4-8 | 137 | Kinetics and the Rate Equation |
| 4-9 | 139 | Activation Energy and the Temperature Dependence of Rates |
| 4-10 | 140 | Transition States |
| 4-11 | 142 | Rates of Multistep Reactions |
| 4-12 | 143 | Temperature Dependence of Halogenation |
| 4-13 | 144 | Selectivity of Halogenation |
| 4-14 | 149 | The Hammond Postulate |
| | 151 | Problem-Solving Strategy: Proposing Reaction Mechanisms |
| 4-15 | 153 | Radical Inhibitors |
| 4-16 | 155 | Reactive Intermediates |
| | 160 | Summary: Reactive Intermediates |
| | 160 | Chapter 4 Glossary |
| | 163 | Essential Problem Solving Skills in Chapter 4 |
| | 163 | Study Problems |
| | | In-Chapter 4-1 to 4-33 |
| | 163 | End of Chapter 4-34 to 4-56 |

**Week of March 30 & April 6: ALCOHOLS, ETHERS, EPOXIDES AND SULFIDES (Chapters 10,
11 and 14)**

Chapter 10: STRUCTURE AND SYNTHESIS OF ALCOHOLS

Read and Study Chapter 10

| | | |
|------|-----|---|
| 10-1 | 417 | Introduction |
| 10-2 | 417 | Structure and Classification of Alcohols |
| 10-3 | 419 | Nomenclature of Alcohols and Phenols |
| 10-4 | 423 | Physical Properties of Alcohols |
| 10-5 | 425 | Commercially Important Alcohols |
| 10-6 | 427 | Acidity of Alcohols and Phenols |
| 10-7 | 430 | Synthesis of Alcohols: Introduction and Review |
| | 430 | Summary: Previous Alcohol Synthesis |
| 10-8 | 432 | Organometallic Reagents for Alcohol Synthesis |
| 10-9 | 435 | Addition of Organometallic Reagents to Carbonyl Compounds |
| | 435 | Key Mechanisms; Grignard Reactions |
| | 442 | Summary: Grignard Reactions |

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|-------|-----|---|
| 10-10 | 443 | Side Reactions of Organometallic Reagents: Reduction of Alkyl Halides |
| 10-11 | 445 | Reduction of the Carbonyl Group: Synthesis of 1° and 2° Alcohols |
| | 448 | Summary: Reactions of LiAlH ₄ and NaBH ₄ |
| | 449 | Summary: Alcohol Syntheses |
| | 454 | Chapter 10 Glossary |
| | 455 | Essential Problem Solving Skills in Chapter 10 |
| | 455 | Study Problems |
| | | In-Chapter 10-1 to 10-29 |
| | 455 | 10-30 to 10-51 |

Chapter 11: REACTIONS OF ALCOHOLS

Read and Study Chapter 11

| | | |
|-------|-----|--|
| 11-1 | 460 | Oxidation States of Alcohols and Related Functional Groups |
| 11-2 | 462 | Oxidation of Alcohols |
| 11-3 | 465 | Additional methods for Oxidizing Alcohols |
| 11-4 | 467 | Biological Oxidation of Alcohols |
| 11.5 | 469 | Alcohols as Nucleophiles and Electrophiles: Formation of Tosylates |
| | 471 | Summary: S _N 2 Reactions of Tosylate Esters |
| 11-6 | 472 | Reduction of Alcohols |
| 11-7 | 472 | Reactions of Alcohols with Hydrohalic Acids |
| 11-8 | 477 | Reactions of Alcohols with Phosphorus Halides |
| 11-9 | 478 | Reactions of Alcohols with Thionyl Chloride |
| 11-10 | 480 | Dehydration Reactions of Alcohols |
| | 484 | Problem-Solving Strategy: Proposing Reaction Mechanisms |
| 11-11 | 488 | Unique Reactions of Diols |
| 11-12 | 490 | Esterification of Alcohols |
| 11-13 | 491 | Esters of Inorganic Acids |
| 11-14 | 494 | Reactions of Alkoxides |
| | 494 | Key Mechanism: The Williamson Ether Synthesis |
| | 496 | Problem Solving Strategy: Multistep Synthesis |
| | 499 | Summary: Reactions of Alcohols |
| | 502 | Chapter 11 Glossary |
| | 503 | Essential Problem-Solving Skills in Chapter 11 |
| | 503 | Study Problems |
| | | In-Chapter Problems 11-1 to 11-38 |
| | 503 | End of Chapter problems 11-39 to 11-63 |

Chapter 14: ETHERS, EPOXIDES AND SULFIDES

Read and Study Chapter 14

| | | |
|------|-----|--|
| 14-1 | 623 | Introduction |
| 14-2 | 623 | Physical Properties of Ethers |
| 14-3 | 628 | Nomenclature of Ethers |
| 14-4 | 631 | Spectroscopy of Ethers |
| 14-5 | 633 | The Williamson Ether Synthesis |
| 14-6 | 634 | Synthesis of Ethers by Alkoxymercuration-Demercuration |

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|-------|-----|--|
| 14-7 | 636 | Industrial Synthesis: Bimolecular Dehydration of Alcohols |
| | 636 | Summary: Synthesis of Ethers |
| 14-8 | 636 | Cleavage of Ethers by HBr and HI |
| 14-9 | 639 | Autoxidation of Ethers |
| | 639 | Summary: Reactions of Ethers |
| 14-10 | 640 | Sulfides (Thioethers) |
| 14-11 | 642 | Synthesis of Epoxides |
| | 645 | Summary: Epoxide Syntheses |
| 14-12 | 645 | Acid-Catalyzed Ring Opening of Epoxides |
| 14-13 | 649 | Base-Catalyzed Ring Opening of Epoxides |
| 14-14 | 650 | Orientation of Epoxide ring opening |
| 14-15 | 652 | Reactions of Epoxides with Grignard and Organolithium Reagents |
| 14-46 | 653 | Epoxy Resins: The Advent of Modern Glues |
| | 655 | Summary: Reactions of Epoxides |
| | 656 | Chapter 14 Glossary |
| | 658 | Essential Problem Solving Skills in Chapter 14 |
| | 658 | Study Problems |
| | | In-Chapter Problems 14-1 to 14-28 |
| | | End of Chapter Problems 14-29 to 14-48 |

Week of April 13: CONJUGATED SYSTEMS, ORBITAL SYMMETRY, AND ULTRAVIOLET SPECTROSCOPY

Read and Study Chapter 15.

| | | |
|-------|-----|--|
| 15-1 | 663 | Introduction |
| 15-2 | 663 | Stabilities of Dienes |
| 15-3 | 665 | Molecular orbital Picture of a Conjugated System |
| 15-4 | 669 | Allylic Cations |
| 15-5 | 670 | 1,2- and 1,4- addition to Conjugated Dienes |
| 15-6 | 672 | Kinetic Versus Thermodynamic Control in addition of HBR to 1,3-Butadiene |
| 15-7 | 674 | Allylic Radicals |
| 15-8 | 676 | Molecular Orbitals of the Allylic System |
| 15-9 | 678 | Electronic Configurations of the Allylic Radical, Cation, and Anion |
| 15-10 | 679 | S _N 2 Displacement Reactions of Allylic Halides and Tosylates |
| 15-11 | 680 | The Diels-Alder Reaction |
| | 680 | Key Mechanism: The Diels-Alder Reaction |
| 15-12 | 689 | The Diels-Alder as an Example of a Pericyclic Reaction |
| 15-13 | 692 | Ultraviolet Absorption Spectroscopy |
| | 699 | Chapter 15 Glossary |
| | 701 | Essential Problem Solving Skills in Chapter 15 |
| | 701 | Study Problems |
| | | In-Chapter Problems 15-1 to 15-22 |
| | 701 | End of Chapter Problems 15-23 to 15-38 |

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Note: These books are located in Room J207. Some of the texts are also located in the College Library. Additional items are located in J207, J211, the Chemistry Laboratories and the College Library.

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