

# CH271-15 Mechanistic and Biological Chemistry

20/21

**Department**

Chemistry

**Level**

Undergraduate Level 2

**Module leader**

Andrew Marsh

**Credit value**

15

**Module duration**

10 weeks

**Assessment**

20% coursework, 80% exam

**Study location**

University of Warwick main campus, Coventry

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## Description

### Introductory description

N/A

[Module web page](#)

### Module aims

Conformation and stereochemistry are crucial in understanding how molecules interact. Initially, compounds containing a stereogenic carbon, (or another element) will be reviewed as an introduction to axial and helical chirality. A discussion of the effect of strain on the conformational preferences in acyclic molecules will lead onto the boat and chair forms of cyclohexane. Elimination reactions in these ring systems will be used to illustrate the requirement of orbital overlap in syn/anti elimination mechanisms. Guidance on elucidating reaction mechanisms using rate data, substituent effects and isotopic labeling will be illustrated with examples of hydrolysis, additions, eliminations and ring closure reactions. Factors that favour the chair conformation of cyclohexanes will inform the conformational preferences of monosaccharides but an additional stereoelectronic factor (the alpha effect) that influences conformational preference in the glycoside bond will also be introduced. The principles of general acid/base and specific acid/base catalysis

will be explained and the importance of these factors in hydrolysis and enzyme catalysis. The second half of the module will be an introduction to biological and medicinal chemistry. The principles of carbohydrate chemistry will be discussed, including stereoelectronic effects and synthetic methods. A more detailed discussion of enzyme catalysis will cover transition state theory and Michaelis-Menten kinetics and the use of enzymes for biocatalysis and enantiomer resolution. An introduction to medicinal chemistry will cover enzyme inhibitors, the role of receptors, and examples of receptor agonists and antagonists for adrenaline, acetylcholine and histamine receptors.

## Outline syllabus

This is an indicative module outline only to give an indication of the sort of topics that may be covered. Actual sessions held may differ.

### Chirality

Chirality in systems lacking a stereogenic carbon atom. Point chirality: tertiary amines, sulfoxides, phosphines. Axial chirality: allenes and hindered biphenyls. Assignment of stereochemistry in these systems. Helical structures: helicenes, other examples. Prochirality and facial chirality Si, Re.

### Conformational analysis

Revision ethane and butane. Newman projections and energy - plots. Terms used include staggered, eclipsed, gauche, anti-conformations. Heats of combustion – comparison of cyclic and acyclic systems leading to concepts of strain (torsion and syn-pentane). Strain in acyclic molecules: 1 consequences on conformations e.g. 1,5-pentane interactions.

6-Membered rings (how to draw). Axial and equatorial hydrogens. Chair (GS), half chair (TS), twist chair (GS), boat (TS). 6-Rings. A-values - gauche and syn-pentane interactions (1,3-diaxial); experimental evidence and linkage to computation (see also workshop on using PC Model).

Ring size strain for cyclopropane, cyclobutane, cyclopentane. Medium rings and transannular strain. Stabilising electronic effects upon conformation. Simple orbital view of organic molecules and orbital overlap. Look at consequences of best donor – best acceptor interactions upon conformation e.g. FCH<sub>2</sub>CH<sub>2</sub>F 'gauche effect'. Sugars and the anomeric effect. Esters and amides; peptide bond; phosphodiester in DNA.

### Introduction to reactivity

Rate determining steps and reaction profiles. Exothermic and endothermic reactions. Early and late transition states. Stereoselectivity and stereospecificity definitions Kinetic and thermodynamic control.

Elimination reactions. Basicity and nucleophilicity: hard and soft; E<sub>2</sub> vs S<sub>N</sub>2. 4pK<sub>a</sub> vs. nucleophilicity. alpha effect E<sub>1</sub> and E<sub>2</sub> elimination reactions: mechanism. a) kinetics and stereochem 4-tBu-cyclohex-OTs cis eliminates with EtO<sup>-</sup> in EtOH, trans does not react. b) orbital alignment c) reaction profiles. Single step reaction. Enthalpy and entropy of activation d) solvent dependence of selectivity.

Syn vs anti-eliminations. E<sub>1</sub>cb reactions: mechanisms a) kinetics and stereochem b) electron withdrawing groups and acidity c) Two step reaction RDS vs slow step (two extreme cases). Changes in rate determining step. Reactions in six-membered rings.

More reactions in 6 membered rings. Rates of ring closure. Ring contractions and fragmentations, Anchimeric assistance.

### Carbonyl reactions

Carbonyl reactions. Additions and additions/eliminations. General trends in reactivity. Sterics and electronics. Kinetics of hydrolysis and esters and amides: data analysis and mechanistic elucidation. Imine formation and hydrolysis. Rates and mechanistic interpretation. AAc1 isotopic labelling.

### Acid and base catalysis

From rate data to a inferring a mechanistic hypothesis. Mechanisms and catalysis – looking at ester hydrolysis and inferring mechanism. Specific acid catalysis, General acid catalysis. Specific base catalysis, General base catalysis. Precise meanings of each term arising from rate data. Enzymatic catalysis – chymotrypsin. Termolecular base amide hydrolysis

### Linear free energy relationships

Mechanistic investigations. Substituent effects. Hammett equation. Sigma (substituents), Rho (reactions). Similarity parameters. Swain-Scott nucleophilicity scales. Brønsted plots. General base catalysed eliminations. general acid catalysed reactions.

### Diastereoselective reactions.

Definitions; measuring diastereoselection. Examples for carbonyl additions. Development of models for understanding experimental results: Felkin-Anh model. Aldol reaction and cyclic 6-membered transition states.

### Isotope Effects in Elucidation of Mechanism

Primary kinetic isotope effects. Secondary isotope effects. Equilibrium isotope effects. What they tell us about the reaction mechanisms.

### Applying stereoelectronic principles.

Non-classical carbocations. Examples of stereoelectronic effects in synthesis. Stereoelectronics of non-first row elements.

### Carbohydrates

Cellular energy and glucose; the structure of D-glucose, anomers and the anomeric effect; the structures and functions of monosaccharides; the glycosidic bond; oligosaccharides – structures and functions of disaccharides and polysaccharides; biosynthesis of oligosaccharides

### Proteins & Enzymes

Protein structure, information flow from DNA to RNA to proteins; Enzyme catalysis, transition state theory, Michaelis-Menten kinetics, selected examples of enzyme catalytic mechanisms; use of enzymes for biocatalysis, resolution of enantiomers

### Introduction to Medicinal Chemistry

Introduction to drug discovery process; enzyme inhibition, examples of enzyme inhibitors; receptors, introduction, structure/function of receptors; selected examples of receptor agonists/antagonists

## Learning outcomes

By the end of the module, students should be able to:

- Understanding of the concept of kinetic isotope effects and its use to determine energetic and geometrical changes.
- Appreciate importance of enantio- and diastereotopism.
- Understanding of the mechanistic concept to describe chemical reactions and awareness of some of the tools to derive mechanistic insight
- Construction of a reaction profile based on kinetic and thermochemical properties of a chemical reaction.
- Confident design of labelling experiments to obtain mechanistic insight into the reaction.
- Understand and explain the structures, reactivity and synthesis of monosaccharides, disaccharides, and polysaccharides; answer problem-based questions on these topics.
- Understand and explain the molecular basis for enzyme catalysis, enzyme structure, and Michaelis-Menten enzyme kinetics; answer problem-based questions on these topics.
- Understand the principles and practices of introductory medicinal chemistry, examples of drug action through enzyme inhibition and receptor binding; assess structure-activity data and answer problem-based questions on these topics.
- Assign C-I-P (R/S) nomenclature to a range of stereogenic centres including non-carbon centres.
- Be able to competently draw a range of three-dimensional molecules in two dimensions and appreciate key stereochemical conventions.
- Appreciate that stereochemistry is not necessarily associated with a stereogenic centre. Give examples of helically and axially chiral molecules.
- Be able to carry out conformational analysis of simple acyclic and cyclic molecules using appropriate diagrams (Newman projections, chair / boat structures).
- Explain the effect of ring size on energy and conformation of small and medium sized rings.
- Explain in mechanistic terms how conformation in cyclic systems directly affects reactions such as base catalysed (E2) eliminations in cyclic systems.

## Indicative reading list

1. Organic Chemistry J. Clayden, N. Greeves, S. Warren, OUP, 2012 2nd Edn [CGWW].
2. Modern Physical Organic Chemistry E. V. Anslyn, D. A. Dougherty University Science Books, 2005
3. Stereochemistry David G. Morris, RSC Books, 2001.
4. Stereoelectronic Effects A. J. Kirby, Oxford Chemistry Primers, 1996.
5. A Guidebook to Mechanism in Organic Chemistry, P. Sykes, 6th Edn., Longman.
6. Molecules in Four Dimensions, <http://wetcbe.cmbi.ru.nl/organic/indexe.html>
7. Chemtube3D.com

## Further Reading

1. Mechanism in Organic Chemistry R. W. Alder, R. Baker, J. M. Brown Wiley, 1971. QD 1722.A5.
2. The search for organic reaction pathways P. Sykes Longman, 1972.
3. Stereochemistry at a Glance J. Eames and J. M. Peach, Blackwell, 2003.
4. Guide to Organic Stereochemistry S. R. Buxton, S. M. Roberts, Longman, 1996, QD1858.B8.
5. Mechanism and Theory in Organic Chemistry, T.H. Lowry, K. S. Richardson, 2nd Edn.,

Harper & Row, 1981, QD 1722.L6.

6. Advanced Organic Chemistry, J. March, 4th Edn., Wiley, 1992, QD 1722.M2.
7. Alicyclic Chemistry, F. J. McQuillan, 2nd Edn., Cambridge, 1983, QD 2310.M2.
8. Physical Organic Chemistry N. S. Isaacs, 2nd Edn., Longman, 1995, QD 1611.I8.
9. Stereochemistry of Organic Compounds E. L. Eliel, S. H. Wilen, L. N. Mander Wiley, 1994, QD1858.E5.
10. Introduction to Enzyme and Coenzyme Chemistry, T.D.H. Bugg, 2nd edition, Blackwells Science, 2004
11. An Introduction to Medicinal Chemistry, G.L. Patrick, 3rd edition, OUP, 2005
12. Biochemistry, L. Stryer, 5th edition, W.H. Freeman and Company, New York, 2001

## Subject specific skills

Numeracy

Problem solving

Written communication

## Transferable skills

Numeracy

Problem solving

Written communication

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## Study

### Study time

Type	Required
Lectures	30 sessions of 1 hour (20%)
Tutorials	4 sessions of 1 hour (3%)
Practical classes	2 sessions of 1 hour (1%)
Other activity	2 hours (1%)
Private study	112 hours (75%)
Total	150 hours

### Private study description

Self-study.

### Other activity description

Revision sessions.

## Costs

No further costs have been identified for this module.

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## Assessment

You do not need to pass all assessment components to pass the module.

### Assessment group D1

	Weighting	Study time
Workshop reports	20%	
Two sequential assessed workshop reports of 2-3 pages. Feedback of report 1 to be provided before 2nd report is submitted		
Online Examination	80%	
<ul style="list-style-type: none"><li>• Online examination: No Answerbook required</li><li>• Students may use a calculator</li></ul>		

### Feedback on assessment

Oral and written feedback on assessed work and tutorials from module leader/ tutors. Cohort level examination feedback provided via Moodle.

[Past exam papers for CH271](#)

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## Availability

### Pre-requisites

To take this module, you must have passed:

- All of
  - [CH161-30 Introduction to Organic Chemistry](#)

### Post-requisite modules

If you pass this module, you can take:

- CH3F9-15 Molecular Pharmacology
- CH3F5-15 Bioorganic Chemistry

- CH3E9-15 Advanced Organic Chemistry and Laboratory
- CH3G3-30 Advanced Chemistry (Organic, Inorganic and Physical) Industrial Placement
- CH414-15 Advanced Molecular Pharmacology
- CH411-15 Advanced Chemical Biology
- CH3F3-30 Advanced Chemistry (Organic, Inorganic and Physical)

## Courses

This module is Core for:

- UCHA-4 Undergraduate Chemistry (with Intercalated Year) Variants
  - Year 2 of F101 Chemistry (with Intercalated Year)
  - Year 2 of F122 Chemistry with Medicinal Chemistry (with Intercalated Year)
- UCHA-3 Undergraduate Chemistry 3 Year Variants
  - Year 2 of F100 Chemistry
  - Year 2 of F100 Chemistry
  - Year 2 of F121 Chemistry with Medicinal Chemistry
- UCHA-F110 Undergraduate Master of Chemistry (with Industrial Placement)
  - Year 2 of F100 Chemistry
  - Year 2 of F110 MChem Chemistry (with Industrial Placement)
  - Year 2 of F112 MChem Chemistry with Medicinal Chemistry with Industrial Placement
- Year 2 of UCHA-F107 Undergraduate Master of Chemistry (with Intercalated Year)
- UCHA-F109 Undergraduate Master of Chemistry (with International Placement)
  - Year 2 of F109 MChem Chemistry (with International Placement)
  - Year 2 of F111 MChem Chemistry with Medicinal Chemistry (with International Placement)
- UCHA-4M Undergraduate Master of Chemistry Variants
  - Year 2 of F100 Chemistry
  - Year 2 of F105 Chemistry
  - Year 2 of F110 MChem Chemistry (with Industrial Placement)
  - Year 2 of F109 MChem Chemistry (with International Placement)
  - Year 2 of F125 MChem Chemistry with Medicinal Chemistry
- Year 2 of UCHA-F127 Undergraduate Master of Chemistry with Medicinal Chemistry (with Intercalated Year)