University of Birmingham

Course breakdown and modules

Read below to find out more about the Chemistry we cover in each year of our single honours (BSc, MSci (hons)) degree programmes.

Each year contains 120 credits of taught material. This is delivered in modules which are typically worth 10 or 20 credits. Core Courses (60 credits in each year) are taken by all students enrolled on both single honours and major/minor degree programmes and cover the fundamental aspects of the subject, which we deem essential. These courses also include a significant practical component in which core practical skills and techniques are developed in a range of experiments, which also allows us to consolidate the theory you will have covered in associated lectures.

Please refer to the **appropriate course web-page (/schools/chemistry/undergraduate/undergraduate-degree-courses.aspx)** for information on the subjects covered in the minor component of our major/minor courses.

If you would like more details about any of our modules, please **contact us (/schools/chemistry/undergraduate/contact.aspx)**.

Please note that we regularly review our degree programmes to ensure our courses remain relevant and at the forefront of the discipline. Modules are therefore subject to minor changes.

Year 1

Open all sections

Structure and Bonding (Core Course)

This module provides an introduction to spectroscopy, structure and chemical bonding, before illustrating these concepts through the chemistry of d-block metals.

- **Spectroscopy and Structure Elucidation**
  The spectroscopy component of this course focuses on how to interpret spectra from some of the most widely used analytical techniques including mass spectrometry, IR spectroscopy, and ^{13}C- and ^{1}H NMR spectroscopy. Particular focus is placed on the development of integrated problem-solving skills in an enquiry-based learning [EBL] approach, using a combination of spectroscopic techniques to determine molecular structure.
- **Structure and Bonding**
  This component of the course focuses on structure and bonding. Atomic structure is introduced, covering concepts such as quantum numbers, electronic configurations and dn-configurations [for transition metals and their complexes], before moving on to the Periodic Table, where trends in physical, chemical and electronic properties of the elements (periodicity) are discussed.
  We will then open up our discussion of structure and bonding with an analysis of covalent bonding, before progressing on to valence shell electron pair repulsion (VSEPR) theory and hybridisation. More advanced bonding models are then introduced, including Molecular Orbital theory and concepts used to understand ionic bonding, which provide a thermodynamic basis for the formation of ionic compounds and the structures of some simple types of extended ionic solids.
- **Chemistry of d-Block Metals**
  The final part of the module focuses on d-block chemistry. Important concepts such as coordination number, oxidation state, denticity and Lewis acid/base theory are covered before introducing Crystal Field Theory and its application to octahedral and tetrahedral transition-metal complexes.

Synthesis and Mechanism (Core Course)

This module introduces some of the most conceptually and practically important reactions in organic chemistry. A mechanistic approach is adopted throughout in that the chemical reactivity and behaviour of organic molecules is explained using molecular orbital descriptions of bonding and fundamental concepts such as electronegativity and polarisation. In taking this approach, we are able to use a relatively narrow range of principles to explain a diverse array of transformations. The module also focuses on how to construct organic molecules from simple starting materials (building blocks) and how functional groups can be added or manipulated selectively and with control.

- **Structure and representation, configuration, conformation and bonding**
  The diagrammatic representations and naming system widely used in degree-level organic chemistry are introduced alongside concepts of isomerism, chirality, configuration and conformation, before moving on to using a molecular orbital approach and the hybridisation of atomic orbitals around carbon to predict and rationalise the structure of organic molecules.
- **Chemical reactivity principles**
  We next consider why molecules react with one another, focusing on the requirements for a molecule to behave as a nucleophile or an electrophile, and the factors that determine relative reactivity. We will look at how substituents can affect acidity (pK_a) through π-resonance and σ-inductive effects and how these concepts can be used to correlate aspects of reactivity such as leaving group ability.
  Having discussed some of the fundamental concepts associated with structure and reactivity, we will look at how to illustrate how molecules react with one another using curly arrow notation in arrow-pushing mechanisms.
- **Synthesis and mechanism**
  Fundamental reactions that are widely used in organic synthesis are introduced in this part of the course. In nucleophilic substitution reactions, we will look at how the S_N1 and S_N1 reaction mechanisms rationalise the reactivity and various outcomes of different types of alkyl halides, and related electrophiles, in their reaction with nucleophiles. This discussion progresses naturally on to elimination reactions in which alkyl halides can be used to form alkenes. E1 and E2 reaction mechanisms are introduced here and used to explain the outcome of this type of reaction.
  The chemistry of alkenes and alkynes is then discussed in more detail. Bonding and reactivity patterns are emphasised, alongside important reactions of alkenes and alkynes and methods for their preparation. Finally, since the versatility of the carbonyl group makes it one of the most important functional groups in organic synthesis, the next section of this module is devoted exclusively to the chemistry of molecules containing this type of functional group.
  The final part of the course functions as a synoptic element. Here we will revise material from the earlier parts of the course in order to consolidate your understanding of fundamental aspects of organic chemistry, including stereochemistry, reactivity and reaction mechanism, and to revise synthetic transformations and reaction selectivity issues.

Kinetics, Thermodynamics and Optical Spectroscopy (Core Course)

Thermodynamics, kinetics and spectroscopy underpin all branches of chemistry by providing simple conceptual models. This course will develop your existing knowledge of these fundamental aspects of physical chemistry.

- **Thermodynamics**
  Thermodynamics provides the essential quantitative framework for understanding both equilibrium and change in the physical world. In this introductory course on the subject, emphasis is placed upon the physical observations that motivate the development of the somewhat abstract concepts used in thermodynamics. The course includes the laws of thermodynamics, the concept of Gibbs free energy and an introduction to chemical equilibria.
- **Kinetics**
  A knowledge of kinetics is central to understanding what drives chemistry and how fast chemistry occurs. After covering the fundamentals of how rates and orders of chemical reactions are defined, we shall explore the temperature dependence of reaction rates and the reasons for this experimental observation. We will then examine some of the methods used to determine reaction rates, the relationship between kinetics and thermodynamics and, finally, how experimental data can be used to determine more complex reaction mechanisms.
- **Optical spectroscopy**

The observation and analysis of spectra is important in all branches of chemistry. You will already have learnt to assign mass, NMR and IR spectra in the Structure and Bonding module. This part of the course now focuses on the fundamentals of spectroscopy, showing that it is a subject in its own right, and far more than just an analytical tool for structure elucidation. The course will focus on diatomic molecules, which we will use to introduce you to rotational and vibrational transitions and the techniques of microwave and infrared spectroscopy, which have been developed into the valuable techniques, used today for determining molecular structure.

Introduction to Analytical Chemistry

This module introduces fundamental concepts of analytical chemistry and will discuss how the analyst detects which substances are present in a sample and determines their concentration using a range of analytical techniques (e.g. atomic absorption spectrometry, flame emission spectrometry, gravimetric and volumetric analysis). Since some samples for analysis are so complex that it is better to separatethem first into their individual components, before determining them, this modulealso provides an introduction to separation science. We will discuss indetail two of the most important separation techniques, namely HPLC and GC.

Numerical Methods

It is essential for chemists to have a good understanding of the mathematical concepts and techniques, which are used widely in the subject. All students therefore take a maths course in Year 1 to develop their confidence in using numerical methods to solve chemical problems.
Those students without A-level Maths take a Numerical Methods course in Semester 1 whilst all students take a Numerical Methods module in Semester 2. Delivered by academics from the School of Chemistry, both courses cover those aspects of Maths (matrices, logs and exponentials, integration and differentiation), which provide essential tools for understanding the more physical aspects of our Chemistry programme. Throughout we will use numerical examples of the problems you will meet in the Physical and Analytical Chemistry modules of the course, to demonstrate the importanceof Maths in Chemistry.

Transferable Skills and IT Training

This module will develop your transferable skills in a number of core areas, focusing on the use of IT and standard word-processing software, as well as more specialised chemistry software programs, such as ChemDraw, Sigmaplot and Equation Editor, which you will use throughout your time in the School. Writing skills, with a particular emphasis on completing lab reports, are also developed.

Additional Modules

Depending on the degree programme, you can also take additional courses. These include:

- **Modules outside the Main Discipline**
  Particularly popular topics from a wide selection available include:
  - ‘ The Cosmic Connection’ (Astronomy and Physics)
  - ‘ Good brain – Bad brain’ (Pharmacology)
  - ‘ Natural Hazards’ (Geography and Environmental Sciences)
- **Modern Language modules**
  Students on our **Chemistry with a Modern Language (/undergraduate/courses/chemistry/chemistry-language-msci.aspx)** programmes and those on the **Chemistry with Study Abroad (/undergraduate/courses/chemistry/chemistry-study-abroad-msci.aspx)** programme, who are intending to study at a non-English speaking University on their year out take a modern language module.

Year 2

Quantum Mechanics and Atomic Spectroscopy (Core Course)

Quantum mechanics is fundamental to our understanding of matter and the way in which atoms and molecules interact with light, i.e. spectroscopy. This course introduces quantum mechanics, starting from its development to explain failures of classical mechanics, through to its application to atoms and in understanding the spectra of one- and many-electron atoms/ions. We shall also discuss how electronic configurations give rise (through electrostatic interactions) to terms, and how these are split by the magnetic coupling of spin and orbital angular momenta into (J) levels, which may be further split into states in a magnetic field.

Non-ideal Thermodynamics and Equilibrium Electrochemistry (Core Course)

Thermodynamics provides an essential quantitative framework for understanding both equilibrium and change in the physical world. This module extends the ideas introduced in Year 1 to non-ideal situations, specifically to those situations where the interactions between atoms, molecules or ions need to be taken into account. The module will explain how these interactions affect the properties of materials and how systems reach equilibrium, before illustrating the importance of some of these ideas in electrochemistry.

X-ray Diffraction (Core Course)

This module introduces X-ray diffraction as a powerful analytical technique for providing detailed structural information of solids. The nature of the crystalline state will be discussed before moving on to show how the diffraction experiment can be used to define key parameters such as the unit cell, space groups and lattice parameters.

Chemistry of the Elements: p-Block (Core Course)

This module focuses on the chemistry of the p-block elements, with the first section covering elemental trends, bonding effects and the chemistry of p-block compounds. The second section focuses on the use of simple band theory to understand the bonding and properties in p-block elements and semi-conducting solids.

Chemistry of the Elements: d-Block (Core Course)

This module discusses the stereochemical and bonding properties of transition metal complexes. The electronic structure of transition metals in coordination and organometallic complexes will be discussed and the donating/accepting properties of ligands reviewed and contrasted in the spectrochemical series. Basic concepts of electronic spectroscopy of coordination complexes will then be correlated to the bonding in metal complexes, before introducing bonding in organometallic transition metal complexes and how this important class of compound finds extensive application in synthetic organic chemistry. In the final section of the course, we will focus on transition metal oxides and fluorides and their solid state structures. The concept of metal–metal bonding in transition metal compounds and the influence that this has on electronic and magnetic behaviour will be introduced.

Synthesis and Mechanism (Core Course)

This course develops the ideas of chemical reactivity principles, structure and bonding and selectivity issues that were introduced in Year 1, and now applies these to more advanced aspects of Organic Chemistry including aromatic chemistry, reactive intermediates, enolate chemistry and physical organic chemistry.

- **Aromatic Chemistry**
  This course introduces the concept of aromaticity, its origins and how this property affects the physical and chemical behaviour of so-called aromatic compounds. Focusing on benzene as the prototypical aromatic compound, we consider its reaction with electrophiles and discuss in detail how substituents on a benzene ring affect the reactivity of the aromatic ring towards further electrophilic aromatic substitution, and how the regioselectivity of this process can be understood and predicted. We finish by examining a selection of heteroaromatic compounds to see how replacing a carbon atom in the aromatic ring for a more electronegative element affects the reactivity and degree of aromaticity of the compound.
- **Reactive Intermediates**
  Building upon their introduction in Year 1, this course further explores the chemistry of reactive intermediates in Organic Chemistry. We will examine the structure, formation, relative stability and reactivity of key examples, including carbocations, carbanions, arynes, radicals, carbenes and nitrenes. The nature of those species you have already met (carbocations and carbanions) will be discussed in more detail, and used as a basis to inform our subsequent discussion of the other reactive intermediates covered in this course, and by extension to reactive intermediates that you will meet later in the degree programme.

- **Physical Organic Chemistry**
  This course takes a problem-based learning approach to examine how experimental physical methods can be used to probe the reactivity of organic molecules. We will explore how aspects of physical chemistry – simple kinetics and thermodynamics – can be used to elucidate reaction mechanisms. Particular emphasis will be placed on the application of primary and secondary kinetic isotope effects and linear free energy relationships to elucidating reaction mechanisms.

- **Enolate Chemistry**
  Having explored in Year 1 the chemistry of the carbonyl group and specifically its application as an electrophile in a variety of bond-forming processes, this course will discuss how carbonyl compounds bearing α-C-Hs can function as nucleophiles. Nucleophilic forms of carbonyl groups include enolates and enols. We will discuss in detail the selectivity issues involved in forming and using these species before exploring their application in a range of important bond-forming processes, including the crossed-aldol reaction.

Determination of Structure

Building on material introduced in Year 1, this course takes the NMR spectroscopy technique further, showing how 2-dimensional NMR experiments provide a particularly powerful method for elucidating molecular structures. The concept of NMR spectroscopy is then extended to molecules containing spin-active nuclei other than 1H and 13C. The emphasis of this course is on problem-solving rather than the underlying theory, which is covered in detail in Year 3.

Symmetry, Group Theory and Vibrational Spectroscopy

In this module, you are introduced to the ideas of molecular symmetry and the power of group theory to analyse and simplify symmetry-related problems in chemical bonding and spectroscopy. The course is delivered through an integrated programme of lectures, each of which is accompanied by a self-learning computer-based workshop. You will also be introduced to rotational and vibrational Raman Spectroscopy and its use in the study of simple diatomic molecules before we extend these concepts and the applications of group theory to the study of more complex molecules using vibrational spectroscopies.

Chemical Electives (choose two from three).

- **Analytical Science**
  This course develops the knowledge and concepts covered in the introductory course in Year 1, and also aims to provide you with an appreciation of the analytical capabilities of, and problems associated with, the application of a number of important instrumental techniques including atomic absorption and emission spectrometry, inductively coupled plasma sources (especially linked to mass spectrometry) and luminescence analysis. Throughout the course, environmental and forensic applications will be used to illustrate the current significance of these techniques.
  All students on the Chemistry with Analytical Science programme (**F180 (http://www.birmingham.ac.uk/students/courses/undergraduate/chemistry/chemistry-analytical-science-bsc.aspx)** / **F181 (http://www.birmingham.ac.uk/students/courses/undergraduate/chemistry/chemistry-analytical-science-bsc.aspx)**) take this module.

- **Bioorganic Chemistry**
  This course provides an introduction into the synthesis, structure, properties and functions of large biological molecules including amino acids and proteins, and nucleic acids in DNA and RNA. Basic ideas used to study enzyme mechanisms, kinetics and catalysis are also developed.
  All students on the Chemistry with Bioorganic programme (**F163 (http://www.birmingham.ac.uk/students/courses/undergraduate/chemistry/chemistry-bio-organic-bsc.aspx)** / **F190 (http://www.birmingham.ac.uk/students/courses/undergraduate/chemistry/chemistry-bio-organic-msci.aspx)**) take this module.

- **Computational Chemistry**
  In this course, you will learn to appreciate the role that computers play in modern chemistry. You will obtain an understanding of how computation relates to a number of areas of chemistry, and how it can help as an investigative tool that is complementary to experimental approaches. The course deals specifically with the modelling of electronic and molecular motions. An overview of the important ideas, including molecular mechanics, conformational analysis, and ab initio methods, is backed up by a practical component which provide hands-on experience.

Science Communication

In this key-skills module, you will undertake group work on an assigned chemistry topic, and learn to appreciate and develop key team-working skills. You will use a range of software packages to produce a piece of written work, requiring research and analysis of literature information, and further develop your communication skills through an oral presentation and the use of new media technologies to communicate your research to a wider audience.

Modern Language modules

Students on our **Chemistry with a Modern Language (/undergraduate/courses/chemistry/chemistry-language-msci.aspx)** programmes and those on the **Chemistry with Study Abroad (/undergraduate/courses/chemistry/chemistry-study-abroad-msci.aspx)** programme, who are intending to study at a non-English speaking University on their year out take a modern language module.

Year 3

Inorganic Chemistry Semester I (Core course)

This module applies the principles and concepts introduced in Years 1 and 2 to a number of topical areas in inorganic chemistry, including electronic spectroscopy of transition metal complexes, the application of transition metal complexes in homogeneous catalysis, and the chemistry of the *f*-block metals.

- **Electronic Spectroscopy of Transition Metal Complexes**
  In order to understand fully the electronic spectra of transition metal complexes, it is important to consider transitions in terms of the energy states of the ion rather than of individual electrons. In this part of the course, you will therefore develop a detailed understanding of energy states and how these can be used to rationalise the spectroscopic properties of transition metal ions.

- **Transition Metal Chemistry and Homogeneous Catalysis**
  This course will extend your understanding of d-block chemistry by considering in detail the bonding, spectra and ligand substitution reaction mechanisms of complexes containing transition metal ions and how this is important in understanding the role of transition metal complexes in catalysis. Focusing on homogeneous systems, this course will highlight the general principles of catalysis, why and how transition metals effect catalysis, and examine a range of important catalytic processes and cycles.

- **Chemistry of f-block metals**
  In this course, we compare and contrast the chemistry f-block elements with that of transition metals (d-block). Particular emphasis is placed on the importance of electronic structures of lanthanides and actinides which determines their chemical reactivity, leading to their distinctive properties and application in analytical, materials, clinical and medicinal sciences.

Inorganic Chemistry Semester II (Core Course)

In the second core Inorganic Chemistry module, our attention turns to the study of inorganic materials in the solid state, with a focus on defects and non-stoichiometry in solids, ionic conductors, layered and porous inorganic solids.

- **Solid State Chemistry – Defects, Non-stoichiometry and Ionic Conductors**
  In these lectures we move away from the idea of perfect lattice structures to examine the wide range of defects that exist in inorganic solids, and how these affect the chemical and electronic properties of a material, which are responsible for the wide-ranging applications of many technologically important materials, in, for example, superconductors.

- **Solid State Chemistry – Layered and Porous Inorganic Solids**
  Layered and porous silicates and phosphates form one of the most widespread and technologically important classes of solids, including many minerals, clays and zeolites. This course explores the synthesis, crystal chemistry, characterisation and uses of the most important systems, with a particular focus on aluminosilicate zeolites. The course concludes with an analysis of mesoporous solids, as well as non-silicate systems such as aluminophosphates and metal-organic frameworks

(MOFs).

Organic Chemistry Semesters I and II (Core Course)

This course extends the concepts and ideas developed in previous years to new aspects of Organic Chemistry including pericyclic reactions and the application of frontier molecular orbital methods, conformational analysis, organic functional group transformations, heterocyclic chemistry, supramolecular chemistry and stereoselective synthesis.

- **Applied Frontier Molecular Orbital Methods**
  The interaction between two reacting molecular components can be represented by an interaction between particular molecular orbitals on each reactant. The extent of any interaction depends upon the approach geometry, the phase relationship of the orbitals, and their energy of separation. Generally, the most important interaction involves the **h**ighest **o**ccupied **m**olecular **o**rbital (HOMO) of one component and the **l**owest **u**noccupied **m**olecular **o**rbital (**LUMO**) of the other, the so-called **f**rontier **m**olecular **o**rbitals (**FMO**s). In this course we will examine how FMOs can be used to explain and predict the outcomes of an important class of reactions referred to as pericyclic.
- **Conformational Analysis**
  A knowledge of the three-dimensional shape of a molecule is crucial to understanding its reactivity. This course revises and reinforces concepts of molecular shape and conformation and introduces ideas such as stereoelectronic control in molecular stability and reactivity. Analysis of likely conformations of acyclic molecules enables the prediction of reaction outcomes, e.g. in reactions of allylic systems, and in addition reactions of chiral carbonyl compounds.
- **Organic Functional Group Transformations**
  Compounds containing main-group elements, in particular boron, silicon, tin, sulfur and phosphorus, are widely exploited in organic synthesis for effecting a variety of reactions. This course discusses some of the most important applications of these elements in key functional group manipulations, with a focus on selectivity issues.
- **Heterocyclic Chemistry**
  Heteroaromatic motifs form the core structures of many medicinally active compounds. This course is designed to familiarise students with the structure, reactivity, main synthetic routes towards, and the principal reactions of, such aromatic heterocyclic compounds. Examples taken from contemporary medicine will be used to highlight the importance of these structures. The emphasis of the course will be on a discussion of synthesis and reactions in terms of unifying principles and patterns of reactivity, and analogy will be drawn with simple functional group reactivity wherever possible. As well as discussing classical methods and uses of heterocycles, this course will also touch upon some of the most recent cutting-edge applications of heteroaromatic chemistry.
- **Supramolecular Chemistry**
  This course provides an overview of the principles and concepts of supramolecular chemistry and how these may be applied to the design and synthesis of receptor ligands that bind various charged and neutral guest species through intermolecular interactions. The course then moves on to describe how intermolecular interactions may be employed in the assembly of interlocked structures and supramolecular devices.
- **Stereoselective Synthesis**
  The *selective* synthesis of chiral molecules remains one of the key challenges of organic synthesis. By exploring how to construct chiral molecules using a range of case studies, this course looks at how these methods are being used in the stereoselective synthesis of organic molecules. Through comparing and contrasting just a few underlying reaction processes you will develop an appreciation for the simplicity and elegance of asymmetric synthesis.

Physical Chemistry: Spectroscopy and Photochemistry (Core Course)

Building on concepts developed in earlier years, this course focuses on two important aspects of physical chemistry, namely spectroscopy, and photochemistry.

- **Electronic Spectroscopy and Photoelectron Spectroscopy**
  In this part of the course, we will focus on how experimental data on the electronic structure of diatomic molecules is provided by electronic spectroscopy and photoelectron spectroscopy. The ability of molecular orbital theory to account for these experimental results will be demonstrated.
- **NMR Spectroscopy**
  Since its discovery 50 years ago, NMR spectroscopy has impacted in all aspects of chemistry and become the pre-eminent tool for structure elucidation not only of small molecules but also macromolecules such as proteins and DNA. Whilst previous courses on NMR spectroscopy have focused on how to interpret NMR spectra, this course will look at the underlying theory, with emphasis on the physical basis and practical aspects of the technique.
- **Photochemistry**
  Photochemistry is concerned with the chemical and physical processes of molecules arising from the absorption of light. After considering the photochemistry of small molecules such as diatomics, we will broaden the discussion to include larger molecules. Applications of photochemistry will be included throughout the course. For example, we will develop the fundamental principles underlying lasers and discuss how femtosecond lasers can be used to follow molecular reactions as they occur.

Physical Chemistry: solids, surfaces and heterogeneous catalysis (Core Course)

A knowledge of the bulk and surface structures of solid-state materials is vital if we are to understand their physical and chemical properties. This module will introduce you to the investigation of solid-state structure, and then to the processes involved at gas-solid and liquid-solid interfaces.

- **Investigating the Properties of Solids and their Surfaces**
  In this part of the course we consider some of the most important spectroscopic, diffraction and microscopy techniques that are used to investigate the properties of solids and their surfaces. The fundamentals of the various techniques will be described before moving on to discuss their applications, scope and limitations.
- **Surfaces – structures, energetics and adsorption**
  In the next part of the course we look at common surface structures and how these often differ from those predicted from the bulk structures. This is followed with a discussion of the experimental challenges facing surface scientists and the techniques that have been developed to determine surface structure. We shall then consider how and why molecules, including gases, might adsorb on a liquid or solid surface, before combining all of these ideas to look at the creation of designer surfaces from larger molecules.
- **Surface Science and Heterogeneous Catalysis**
  Despite its industrial importance, heterogeneous catalysis remains poorly understood, which is in part due to the structural complexity of many solid catalysts, the difficulty of characterising the active species and the exact processes occurring on solid surfaces. This course will discuss some of the principles behind gas-solid and liquid-solid catalysed reactions and show how a knowledge of surface science and solid-state chemistry can help to develop a rational understanding of the topic. Ideas will be illustrated with case studies of a number of industrially important heterogeneous catalytic processes involving metals and metal oxides, including the Haber-Bosch Process, Fischer-Tropsch Chemistry and the Three-way Catalyst.

Chemical Electives (choose one).

- **Analytical Science**
  In this course we introduce several new topics, especially relating to the application of certain advanced analytical techniques to real-life situations. These lectures will describe how analytical procedures are integrated into methods for particular purposes and how decisions about analytical strategy are reached. The course is composed of three principal topics, namely:
  • Forensic Chemical Analysis
  • Applied Clinical Analysis
  • Advanced Mass Spectrometry
  All students on the Chemistry with Analytical Science programme (**F180 (http://www.birmingham.ac.uk/students/courses/undergraduate/chemistry/chemistry-analytical-science-bsc.aspx)** / **F181 (http://www.birmingham.ac.uk/students/courses/undergraduate/chemistry/chemistry-analytical-science-bsc.aspx)**) take this module.
- **Bioorganic Chemistry**
- **Biosynthesis**

The first part of this course focuses on biosynthesis, which is the term used to describe how Nature makes organic molecules. A range of compound classes will be discussed including fatty acids, polyketides, steroids, terpenes and shikimates. Being taught from a problem-solving viewpoint, you will become familiar with the elucidation of biosynthetic pathways using a combination of isotopic labelling and NMR spectroscopic data.

- **Enzymes and how they work**
  The second part of the course is concerned with the structure, function and kinetics of enzymes. It builds on the material developed in the Year 2 bioorganic elective and includes computer-based workshops to explore protein structure.
  All students on the Chemistry with Bioorganic programme (**F163 (http://www.birmingham.ac.uk/students/courses/undergraduate/chemistry/chemistry-bio-organic-msci.aspx)** / **F190 (http://www.birmingham.ac.uk/students/courses/undergraduate/chemistry/chemistry-bio-organic-msci.aspx)**) take this module.

- **Computational Chemistry**
  This course builds on the Year 2 course and is divided into four parts to illustrate different aspects of computational chemistry. We will cover simulation methods, genetic algorithms and swarm intelligence for search and optimisation, as well as computer programming and the use of computer simulations to study biochemical problems.

Special Chemical Topics (choose three)

- **Chemistry of Magnetic Materials**
  Inorganic solid-state materials are used in many technologically important applications, including components in computer data storage devices and sensors. This course provides an introduction to magnetism in solids and an insight into the current research in magnetic-materials chemistry, through a description of some important applications and the solids that are employed. This will also lead to a discussion of the present understanding of how properties of solids can be related to their structure.

- **Bioinorganic and Coordination Chemistry**
  In this course we will explore the role of inorganic chemistry in biology. Without an understanding of metal coordination chemistry principles, it would be challenging to appreciate the role of a metal in a biological environment. As such, this course re-emphasizes some basic principles, reinforcing them with real examples found in Nature.

- **Retrosynthesis**
  Retrosynthetic analysis is a commonly employed planning strategy carried out prior to undertaking the actual forward synthesis of a target molecule. In this course we will take a workshop approach to discuss the principles behind the retrosynthetic analysis technique. There will be a considerable synoptic element to the course with the target molecules, selected from pharmaceuticals, agrochemicals, natural products, flavours and fragrances, also being chosen for their suitability to be synthesised using methods and reagents which you will have seen in earlier courses.

- **Metals in Organic Synthesis**
  Modern synthetic organic chemistry is heavily reliant on the use of metals, which often serve as catalysts for important bond-forming processes. Moreover, the use of transition metals and lanthanides opens up reaction pathways that are not available through “classical” reactive intermediates. In this course you will be introduced to some of the most interesting and useful metal-mediated transformations in organic synthesis. Although the course is framed around applications in organic synthesis, knowledge of the properties of the metal and its associated ligands is critical to the understanding of the processes involved, and hence there is much overlap with core material in inorganic chemistry, particularly organometallic chemistry, as well as organic chemistry.

- **Atmospheric Chemistry**
  The state of our atmosphere, and how mankind is changing it, is arguably the most important process occurring on Earth in our lifetimes. In this course we will put some scientific flesh into understanding how the Earth’s atmosphere works, and how it has responded to changes over the last 300 years. Atmospheric Chemistry is an excellent example of how chemical kinetics can be used in an applied context and will also provide invaluable backup to the core courses on Spectroscopy and Photochemistry.

- **Magnetic Resonance Imaging (MRI)**
  In this course we will explore the application of NMR as an imaging technique and show how this technique can be used to probe chemical and physical properties spatially and non-invasively. Images are produced through the use of magnetic field gradients and image contrast relies on differences in spin density, relaxation time, chemical shift or diffusion coefficients of molecules within the system. This course will revise the principles of NMR spectroscopy before moving on to describe the hardware, theory and techniques required in MRI. Applications of this technique in the fields of chemistry, materials science, chemical and petroleum engineering, food sciences and medicine will be discussed.

Additional Modules

Students on BSc programmes undertake a research project in this, their final year, whilst those students registered on MSci programmes undertake an advanced laboratory module.

Modern Language modules

Students on our **Chemistry with a Modern Language (/undergraduate/courses/chemistry/chemistry-language-msci.aspx)** programmes take a modern language module.

Students on the Chemistry with Industrial Experience programme (F104 (/undergraduate/courses/chemistry/chemistry-industrial.aspx)) spend their third year out on their industrial placement. In addition to writing up their industrial research in the form of a project report, core material from our Year 3 course is delivered as distance-learning modules, which allows them to return in Year 4 and re-join their cohort to study our advanced Masters courses.

Students on Chemistry with Study Abroad programmes (F106 (/undergraduate/courses/chemistry/chemistry-study-abroad-msci.aspx)) spend their third year studying at one of our partner institutions in Europe or further afield, before returning to Birmingham to complete their fourth and final year of their degree (Year 3 courses for the BSc (F102), Year 4 courses for the MSci (F106)).

Year 4 (MSci only)

The course content in the final year of our MSci programmes has a significant level of flexibility, which allows you to specialise in a particular sub-discipline should you wish. The choice of courses at this level also reflects the state-of-the-art of the discipline and also allows us to showcase the cutting-edge research interests of the School.

In addition to 40 credits of taught material, you will also join one of the School’s research groups to undertake a major research project (worth the remaining 80 credits) in a subject of your choosing. After identifying a particular research area, you will work closely with your project supervisor to tailor the project to your particular research interests.

With the School having expertise in all fields of chemistry, projects range from chemical biology and organic synthesis right through to experimental physical chemistry and computational chemistry.

Applications of Supramolecular Chemistry

In this module we will look at applications of molecular and supramolecular systems based on their photochemical and electrochemical properties. The material will emphasise how in-depth knowledge of molecular properties can provide an understanding of how devices and functional supramolecues can be assembled for particular applications such as luminescent and redox sensors, ion transport, imaging, solar energy conversion systems and photo-driven devices.

- **Luminescent systems: from molecular to supramolecular design**
  A central learning outcome of this course is “how to build” multi-component assemblies to achieve a sophisticated system that can perform functions not realised by simple molecular units. To this end, we will showcase the design of supramolecular structures with useful functions ranging from solar energy conversion systems and molecular electronics to luminescent probes and biological imaging in cells. The importance of intermolecular interactions will be emphasised throughout by

examining the formation and properties of selected classes of supramolecules. The photophysical functions of supramolecular systems and how these allow their use to mimic biological tasks will also be presented.

- **Supramolecular devices**
  The aim of this course is to describe how the concepts of supramolecular chemistry may be applied to the design of functional supramolecular devices. We will pay particular attention to systems where an external input (such as light) changes a property in a reversible manner. Emphasis will be placed on recent developments and potential applications.

Materials Chemistry

- **Biomaterials**
  Biomaterials science is the study and application of materials to problems in biology and medicine. Advanced biomaterials are now regularly employed in devices ranging from heart valves and hip joint replacements, to many aspect of cosmetic and reconstructive surgery. Understanding the chemistry of biomaterials is crucial in their development and successful application. After providing a general background to the field, we will concentrate on how various materials, including polymers, alloys and ceramics, can be used as biomaterials in a range of biomedical devices.

- **Chemistry of the hydrogen economy**
  The idea that hydrogen might be the fuel to provide for mankind's energy needs can be traced to Jules Verne (ca 1870) and is currently receiving fresh impetus as realisation of the long-term unsustainability of fossil-fuel use begins to dawn. Although the multidisciplinary technology required to make the hydrogen economy a reality is in many areas, well advanced, formidable scientific challenges remain. This course addresses all aspects of the use of hydrogen as an energy carrier, with particular emphasis on the chemistry involved.

- **Chemistry and applications of ionic conductors**
  With applications from batteries to fuel cells, solid-state materials displaying high ionic conductivity are currently attracting considerable attention. In this part of the course, we will address the basic features of ionic conduction in solids, as well as their applications with a focus on Li ion batteries and solid-oxide fuel cells.

- **High pressure chemistry**
  The application of high pressures to solids can lead to a wide range of changes in structural and physical, especially electronic, properties. The nature and types of changes will be discussed, using topical examples to develop general principles. Additionally, examples of the high-pressure synthesis of materials with unusual structures, bonding and/or oxidation states will be presented and discussed.

Total Synthesis of Natural Products: Design Strategies and Concepts

- This advanced organic synthesis course will bring you up-to-date with the cutting edge of Organic Chemistry through the use of natural product synthesis to showcase the latest developments in design and synthesis.

  The development of elegant and creative synthetic approaches to complex natural products represents a major challenge to the chemistry community. Often driven by the potential biological applications of the final products and their non-natural analogues, the understanding gained from a natural product synthesis can also have much wider impact on molecular synthesis in general. As well as providing a stern testing ground for recently developed methodologies, advanced synthesis can also be the inspiration for the design of powerful new reactions.

  In this course we will discuss some of the issues that arise when devising a total synthesis, and outline some of the strategies and latest advanced synthetic methods that are being used to realise the synthesis of increasingly complex natural products.

  In addition to these lectures, workshop sessions will examine in detail the synthesisof selected complex natural products. We will analyse the synthetic strategy employed using different approaches and highlight how some of the concepts and advanced synthetic methods discussed earlier in the course address key selectivity issues and in doing so, can be used to assemble complex molecule targets in efficient and creative ways. Thisfinal set of case studies provides valuable preparation for the module assessment,which will involve a critical analysis of a total synthesis of a natural product.

Biological Chemistry

This course looks at science at the interface of chemistry and biology with an emphasis on carbohydrates and their role in biology, and the role of metals in medicines and biological systems.

- **Biological carbohydrate chemistry**
  In this part of the course we will focus on carbohydrates and their importance in biology. We will study how glycosidases hydrolyse glycosidic bonds in vivo. We will look in detail at the mechanism of this reaction for both inverting and retaining glycosidases and discuss the methods that have been used to elucidate this reaction mechanism. Having examined how Nature cleaves glycosidic bonds, we will move on to the reverse reaction and discuss how glycosyl transferases catalyse the formation of glycosidic bonds, with a particular focus on how these enzymes are used in the biosynthesis of the core oligosaccharide of all asparagine-linked glycoproteins.

  Using the ABO blood group system as an example, we will then investigate the relationship between genetic information contained within DNA, the proteins it encodes and the final oligosaccharide they produce. We will expand ideas on enzyme kinetics from looking at a single enzyme to a consideration of enzymes in a pathway and how the rates of the various enzymes might affect the overall rate through the pathway.

  Finally we will look at the role of glycoproteins in the recognition of target T-cells by the HIV virion and explore strategies for drug design targeting this interaction. In this part of the course you will be encouraged to support your learning with your own library research.

- **Bioinorganic chemistry and applications of metals in medicine**
  In the second part of this course we will examine the important role that metals play in biology. We will study zinc-containing enzymes, and their role in hydrolysis reactions, before moving on to discuss the role of metalloenzymes, including heme proteins and cytochromes, in biological electron-transfer mechanisms. Throughout, we will concentrate on the key role that the metal plays in the mechanism of action of the enzyme.
  We will then move on to look at how we can exploit the properties of metals in medical applications, and spend time looking at platinum complexes in cancer therapy, gold complexes in the treatment of rheumatoid arthritis and the use of lithium therapies to control mental disorders, as well as the problems associated with the use of metals in a biological system.

Topics in Physical Chemistry: Spectroscopy, Theory, Kinetics and Dynamics.

- **Theoretical considerations: statistical thermodynamics**
  In the first part of this module, we explore the theory of statistical thermodynamics which provides the link that connects the microscopic and macroscopic descriptions of nature. The former is our molecular picture of chemistry, the world of atomic particles described by quantum mechanics; the latter our everyday experiences of matter in terms of heat, pressure and other properties, the subject of thermodynamics. The central pillar of statistical thermodynamics is the well-known Boltzmann distribution, which governs the accessible energy levels at a given temperature. Combining this with the concept of entropy, we see how we can calculate the thermodynamic functions using the molecular energy levels of a particular molecular system.

- **Microscopic gas-phase processes: kinetics and reaction dynamics**
  In this section of the module we will examine the fundamentals of uni- and bi-molecular reaction kinetics. We will survey theoretical treatments of such reactions, emphasising the connection between the rate coefficient and the underlying potential energy surface for the reaction. Transition state theory is covered in detail using ideas from statistical mechanics, to show how rate constants can be calculated from first principles.
  We will then move beyond the thermal rate coefficient in our quest to probe experimentally the potential energy surface, as we enter the realm of reaction dynamics. This topic – what really happens as chemical bonds break and make during individual reactive encounters – lies at the heart of chemistry. Dramatic technological advances, mainly in lasers and molecular beams, have led to remarkable progress in this field in the last 20 years (including two Nobel prizes). We will review the main techniques and the underlying scientific background given to these experiments, where possible using real examples to give a flavour of recent research and where the subject is heading.

- **Symmetry and spectroscopy of polyatomic molecules**
  In this final part of the module, we will discuss the electronic structures and electronic spectra of polyatomic molecules and the dependence of geometry on

electronic structure, with particular emphasis on group theoretical symmetry-based analysis. Symmetry will also be used to understand vibronic coupling and to explain vibrational structure in the photoelectron spectroscopy of polyatomic molecules.

Topics in Advanced Physical Chemistry: Nanoparticles, Interfaces and Solids

Physical Chemistry can be studied over a wide range of length scales and dimensionalities, from the macroscopic properties of bulk matter down to the structure and behaviour of atoms and molecules that make up all materials. How does the structure of a material affect its properties? To answer this question, we will start with chemistry in three dimensions, looking at how molecules assemble into three-dimensional structures and how these affect the properties and formulation of commercial materials, before moving on to zero-dimensional systems, where the theoretical description, formation and properties of nanoscale clusters and the extent to which their properties are distinct from those of both atoms and bulk matter can be discussed. Finally, we will consider two-dimensional systems, focusing on processes occurring at solid–liquid interfaces, and in particular, at catalytic reactions and tailored surfaces.

- **Molecular solids**
  This course will introduce you to the field of three-dimensional molecular solids (of key importance in pharmaceuticals, agrochemicals, pigments, superconductors), and highlight some key areas of contemporary interest in the area. Physical and chemical properties (such as stability, bioavailability, colour, magnetic and optical properties) of molecular solids depend crucially on crystal structure. We will therefore investigate how molecules pack together in a molecular solid, and in doing so, gain insight into the relationships between structure and properties, and how this knowledge can be exploited in the design of solids with specific desired structures. Applications in the development of technologically important materials, their chemical modification and formulation to improve their efficacy and effectiveness in applications will be discussed.
- **Metal nanoparticles and nanoalloys**
  Clusters bridge the gap between small molecules and bulk materials and range from a few to many millions of atoms or molecules. In the nanometre size regime, they are generally termed “nanoclusters” or “nanoparticles”. In this part of the course, we will focus on metal clusters and bimetallic “nanoalloys”. We will discuss clusters, how they can be generated and studied experimentally and the theoretical models which have been put forward to explain their properties and how these properties vary with size, composition and degree of mixing.
- **Modern interfacial chemistry and electrochemistry**
  Electrochemistry is not just about the Nernst equation; more often than not, it is about control: if we apply an electric potential we can control reactions and structures. Many research fields employ electrochemical techniques to synthesise and characterise compounds, to study biochemical processes, to detect trace quantities, to recycle waste and destroy pollutants. It is also a vibrant area of research in its own right.
  These fields all rely on the same fundamental concepts. We shall start with a current area of research, namely that of catalytic reactions used in fuel cells, and decide what we need to learn more about to understand these reactions and how to improve them. We will then learn about these different areas in the context of the reactions to gain an understanding of current research in this area. We will also look at other examples as we go along to see how the knowledge and methods can be applied to study surface chemistry, organic and biologically modified surfaces and reactions of organic molecules.