



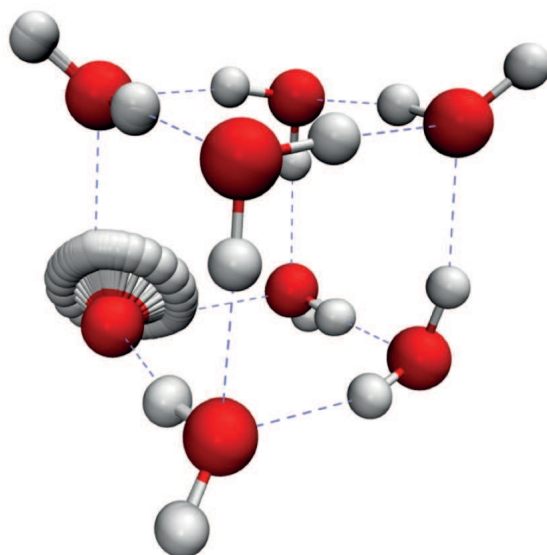
UNIVERSITY OF  
CAMBRIDGE

Yusuf Hamied Department of Chemistry

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**Part III Chemistry:**  
***A Guide to the Course***

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***Academic Year 2021/2022***



The Department of Chemistry endeavours to develop an inclusive, supportive and intellectually stimulating environment for our undergraduate community.

Athena SWAN is an ongoing program to address the underrepresentation of women in the sciences. The Silver Award recognises the progress that the Department has made in recent years, and the actions that benefit not only our female students, but all our undergraduate chemists.

Information about activities and profiles will appear inside the front cover of your lecture handouts.

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## **1 Introduction**

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The fourth year – Part III – is in many ways quite different to the preceding years and we hope that you will find that your final year is a challenging and exciting finale to your undergraduate career in Cambridge.

There are just two components to this year's work. Firstly, a series of advanced lecture courses which will explore topics in which members of the Department are actively engaged. A wide range of topics are on offer, reflecting the enormous breadth of research work undertaken in the

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The picture on the cover is taken from Professor Stuart Althorpe's website and shows an 'instanton' in the water octamer. For further details concerning research in the Althorpe group see <http://www-stuart.ch.cam.ac.uk>

Department and each course aims to take you to the 'research frontier' so that you can begin to obtain a feel of just where modern chemistry is going.

The second component of the course is a sixteen-week research project covering the Michaelmas and Lent Terms. You have already selected the research group you will work with, and over the coming weeks you will begin to get involved in their work. The experience you have gained in the practical classes and in the computer room over the past three years should have given you a solid base of experience and skills which you can bring to bear on your research topic.

A lecture programme includes three interdisciplinary courses (I1, I2 and I3) in the Lent Term. These courses have been designed to address topics which cross the traditional boundaries between chemistry, physics, earth sciences and geography. One of the courses, I1 *Atmospheric Chemistry and Global Change*, is hosted by the Department of Chemistry and given principally by our own staff. We encourage you to have a careful look at the other two courses and see if they catch your interest. These courses present a good opportunity for you to widen your horizons.

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## 2 **Introductory and safety talks**

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**On Wednesday 6th October at 16:00** in the BMS Lecture Theatre there will be introductory talks about the course and in particular about the research project; it is vital that you attend.

**On Wednesday 6th October at 16:00 the introductory talk will be followed by a Safety Lecture also in the BMS Lecture Theatre. The Head of Department requires all new Part III students, without exception, to attend this talk.**

You will not be able to start your project unless we have a record of your attendance at this safety lecture.

**Please enter and exit via the BMS foyer only**

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## 3 **Careers for chemists**

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On 18th October at 17:00 Dr Raj Sidhu, from the Careers Service, will give an online presentation on Careers for Chemists. The details for joining this event will be circulated nearer the time.

Even if you are thinking of carrying on for a PhD it is as well to inform yourself about other career options, and Dr Sidhu's talk is therefore highly recommended for all the class.

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## 4 **Outline of the course**

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### *Lectures*

There are a total of seventeen separate lecture courses on offer. The courses offered in the Michaelmas Term are denoted M1, M2 . . . and those in the Lent Term L1, L2 . . . Several of these courses are interdisciplinary and cross the traditional divisions of the subject, so before making your decision as to which courses to attend, please do read the synopses carefully. In addition, there are the three Interdisciplinary Courses I1 – I3 run in conjunction with other departments.

The structure of the examination (see page 26) is such that you will need to answer questions on *three* separate courses from the Michaelmas Term and *three* separate courses from the Lent

Term. You may choose to prepare more than this minimum of six lecture courses: this will give you more choice in the examinations, but will of course increase your workload. In any case, you will probably want to attend several lectures from a course before deciding whether or not to pursue that course fully.

Apart from the requirement to take a minimum of three courses in the Michaelmas and three in the Lent Terms, you have a completely free choice as to which lectures to follow. Lectures are confined to weekday mornings, leaving you the afternoons free for supervision and project work. There are no lectures in the Easter Term.

You should think carefully about which courses to follow, and should seek advice from your Director of Studies; other members of staff will also be happy to advise, as will the Director of Teaching.

### *Research project*

The way in which your project operates will depend very much on the group you have chosen to work in. However, whatever the topic, you should expect to find the work more challenging than conventional set practical; research is, by its very nature, an exploration of the unknown and so results cannot be guaranteed.

The project will be assessed on the basis of a written report which you will submit at the start of the Easter Term, a report from your supervisor and an interview. The assessment is not based on the results obtained – this would be unfair as results cannot be guaranteed – but is based on the commitment and aptitude you have shown and how well you have written up the account of your work.

You are required to give at least one formal presentation, either to your research group or to a larger gathering, as part of your project work.

## **5** \_\_\_\_\_ **Lecture synopses: Michaelmas Term**

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### **M0: Advanced polymer chemistry**

*Prof. Oren Scherman (9 lectures) and Dr Hugo Bronstein (3 lectures)*

The course will cover the synthetic methodologies used to prepare polymers. A quantitative and mechanistic approach for these polymerisations will be discussed in detail. Preparation of co-polymers and functional polymeric materials and their useful applications will also be covered.

This course assumes knowledge of the organic chemistry covered in Part II as well as the Part II course C11 Polymers: synthesis, characterisation and application. This course is now labelled as B8

**Topics** Synthesis of macromolecules: chain vs step polymerization

Detailed reaction mechanisms and kinetics

Molecular weight and topology

Characterisation techniques and analysis

Polymer properties in solution & bulk

Block copolymer preparation methods

Functional polymers & applications

### **Recommended books**

Principles of Polymerization, 4th Edition, G. Odian, 2004, John Wiley & Sons. [QD281.P6.035]  
Polymer Chemistry: An Introduction, 3rd Edition, M.P. Stevens, 1999, Oxford University Press. [QD381.S74]  
Handbook of Polymer Synthesis, Part A, Ed H.R. Kricheldorf, 1992, Marcel Dekker. [TP1130.H36]  
Polymer Chemistry & Physics, 2nd Edition, J.M.G. Cowie, 1991, Blackie. [QD381.C69]  
Introduction to Industrial Polymers, 2nd edition, H. Ulrich, 1993, Hanser. [TP1087.Y47]  
Polymer Physics, U. Gedde, 1995, Chapman & Hall. [QD381.8.G43]

## **M1: Inorganic materials**

*Dr Paul Wood*

The course will describe the magnetic (and electronic) properties of molecular solids, extended networks and metal oxides, and show how unusual properties can be rationalised from knowledge of the compounds' structures. The material will be illustrated by real examples and the course will progress from fundamental theory to the most up-to-date topics in molecular magnetism such as the search for highly efficient data storage compounds using clusters and chains. Methods for measuring magnetism and magnetic phenomena directly and indirectly will be discussed including heat capacity measurements and neutron diffraction.

It is desirable, but not essential, to have taken the Part II Course *C3: NMR*.

**Topics** Fundamental properties in magnetism; diamagnetism, paramagnetism and magnetic susceptibility.

Magnetic properties of isolated ions; understanding the behaviour of first-row transition metals and lanthanides including the van Vleck equation to model their magnetic behaviour.

Extensions to a wider series of oxides including perovskites, spinels and garnets (including a brief description of the different structures and the basic crystallographic notation used to describe them).

Trends across the 3d series: from delocalised (metallic) to localised paramagnetic (magnetic) properties.

An introduction to magnetic anisotropy focusing on single ion anisotropy.

Magnetic properties of clusters; Communication between unpaired electrons via direct exchange and superexchange pathways; models for the magnetism of clusters using Kambe's vector coupling approach; single molecule magnets.

Magnetic properties of extended networks; ferro-, ferri- and antiferromagnetism; molecular field theory. Exotic types of ordering such as metamagnetism, canted antiferromagnetism and spin flop phases. Spin frustration. Single chain magnets.

Characterisation methods such as heat capacity measurements and neutron diffraction leading to magnetic phase diagrams.

Double exchange and magnetic phenomena; high-spin low spin transitions; uses of magnetism and magnetic materials in devices/applications

## **Recommended Books**

*Magnetism and Transition Metal Compounds*, Carling, R.L., and van Duyneveldt, A.J., Springer-Verlag, 1977 [Not held in the Chemistry library]

*Molecular Magnetism*, Kahn, O., VCH, 1993 [QD940.K34]

*Magnetism and Transition Metal Complexes*, Mabbs, F.E., Machin, D.J., London, 1973 [QD474.M33]

*Magnetochemistry*, Orchard, A.F., Oxford, 2003 [QD591.O73]

*Magnetism in Condensed Matter*, Blundell, S., Oxford, 2001 [QC173.458.M33.B58]

## M2: Bio-Inorganic chemistry

*Dr Paul Barker*

This is not a traditional bioinorganic course. It brings together fundamental aspects of inorganic chemistry with biological chemistry to examine how and why biology uses the metals it does. The basis of the course deals with the interaction of inorganic cofactors with biological molecules (mainly proteins) and how the fundamental chemistry of metallic elements is controlled and manipulated for catalytic and structural chemistry. This will be illustrated by structural spectroscopic and mechanistic insights into proteins and enzymes using zinc, iron and copper as paradigms. Fundamental to this is the chemistry of dioxygen O<sub>2</sub> - specifically, its coordination and redox properties. We will also look briefly at molybdenum and cobalt systems.

Once we have considered how the chemistry of metallic components of biology are manipulated by biomolecules (and *vice versa*), we will examine the principles underlying the use of metallic cofactors in complex, highly organised structures seen in natural charge transfer processes. We will discover how multiple redox centres can be organised in a variety of ways for harnessing electrochemical and photochemical potentials and also consider what we can learn from biological systems for the construction of useful molecular electronic devices. Along the way we will examine how biology acquires metal ions and regulates their concentration in cells. This will lead on to a consideration of the biological chemistry of heavy metals (e.g. Pb, Cd, Pt and Ru) and their interactions with nucleic acids and proteins. The course will finish by looking at the very topical embryonic field of artificial metalloenzymes in the context of synthetic biology.

This is a highly interdisciplinary course and calls upon basic chemistry encountered in IA and IB courses. We will need to think about metal ion properties (Chem B level) including redox chemistry and ligand exchange (Part II courses A1 and B1), as well as some simple IA biochemistry. Prior knowledge of basic biomolecular structures, particularly proteins, is helpful but not essential. I do not aim to deliver or test biochemical knowledge, rather to uncover the fundamental metallochemistry that biology uses in an amazing variety of ways. My goal is not to ask you to remember specific reactions (well, not many) but rather to understand how metal ion chemistry is manipulated and structured in biology so that you can analyse unseen cases.

**Topics Lectures 1-8:** Basic metalloprotein chemistry: coordination, thermodynamics, structure and catalysis, exemplified by zinc, iron, copper, molybdenum and cobalt.

**Lectures 9-10:** Organisation and principles of electron transfer in biological systems.

**Lectures 11-12:** Engineering unnatural metal cofactors and artificial metalloenzymes for medicine and synthetic biology.

### **Recommended books**

*Principles of Bioinorganic Chemistry* Lippard S.J. and Berg J.M. University Science Books, 1994 ISBN: 0935702725.

*The Biological Chemistry of the Elements* Frausto da Silva, J.J.R. and Williams, R.J.P. 2nd ed. OUP 2001 ISBN: 0198508484.

*Review articles and original publications will be highlighted and made available where useful*

## M3: Soft matter – from molecules to materials

*Prof. Tuomas Knowles (6 lectures) and Dr Thomas Michaels (6 lectures)*

Soft materials are systems which are readily deformed by thermal fluctuations or mechanical stresses. Many of the objects and materials in the world around us deform when squashed, can flow or are sensitive to temperature changes. These types of materials, including paint, yoghurt, shampoo, rubber and foam are all thus soft materials. Concepts from soft matter also allow us to understand materials in biology; living matter is for the large part soft matter. As such the study of soft matter is an area with a rich set of interdisciplinary connections. The properties of soft

matter systems are not used just in nature. They are also key for technological applications, including in engineering everyday products such as plastics, foods, creams and gels. This course will focus on the fundamental physical principles that allow us to understand, predict and control the behaviour of some of the most important classes of soft materials: polymers, liquid droplets, self-assemblies, colloids, surfactants, and biological membranes.

### **Recommended Books**

*Nanoscale Materials in Chemistry*, Ed K. J. Klabunde [TA418.9.N35]  
*Characterisation of Nanophase Materials*, Ed Zhong Lin Wang [TA418.9.N35.C43]  
*Introduction to Modern Colloid Science*, R. Hunter [QD549.H36]  
*Surfactants and Polymer in Aqueous Solution*, Jonsson et al. [TP994.S87]  
*Basic Principles of Colloid Science*, D.H. Everett [QD549.E94]  
*An Introduction to Ultrathin Organic Films, from Langmuir-Blodgett to Self-Assembly*, A. Ulman [QC176.9.O73.U46]  
*Surfactants and Interfacial Phenomena*, M.J. Rosen [TP994.R67]  
*The Colloidal Domain*, D.F. Evans and H. Wennerstrom [QD549.E93]

## **M4: Energy landscapes and soft matter**

*Dr Robert Jack (6 lectures) and Prof. David Wales (6 lectures)*

### *Soft Matter*

We give an overview of some important classes of soft materials, including colloids, liquid crystals, and polymers. We focus on three main questions: First, what are the interparticle interactions that control the behaviour of these materials? Second, what is the resulting phase behaviour? Third, what are the relevant time scales (and transport properties)? For the first question, examples include electrostatic interactions, depletion forces, and excluded volume effects. For the second, we focus on colloidal phase behaviour, including colloidal crystals and liquid crystal phases. For the third, examples include homogeneous nucleation and electrokinetic flow.

The course builds on material discussed in the Part II course *Statistical Mechanics* (B6).

### *Energy Landscapes*

The study of potential energy surfaces, or “energy landscape”, is of central importance in addressing a wide range of scientific problems in chemical and condensed matter physics. This part of the course will introduce the basic theoretical framework for describing and exploring energy landscapes and will demonstrate how this framework can be exploited to understand the observed structure, thermodynamics, and dynamics of a system.

Several case studies will be considered, illustrating applications to clusters, biomolecules, supercooled liquids, and soft matter systems.

A background of the Part II course *Statistical Mechanics* (B6) will be assumed.

Example classes are offered during the course and supervisions may be requested in the Easter term.

### **Recommended books**

J. L. Barrat and J. P. Hansen, *Basic concepts for simple and complex liquids*, Cambridge University Press, 2003. [QC145.2.B37]  
D. J. Wales, *Energy Landscapes*, Cambridge University Press, 2003. [QD462.6.P64.W35]



## M5: Stereocontrolled organic synthesis

*Dr Alex Fawcett (3 lectures), Dr Aaron Trowbridge (3 lectures) and Prof. Jonathan Goodman (6 lectures)*

Modern organic synthesis plays a key role in providing useful quantities of organic compounds, which include natural products and their structural analogues for biological evaluation, new materials, and molecules with diverse chemical structures and properties.

This course aims to add to your range and understanding of important chemical reactions used in modern synthetic chemistry, with an emphasis on how they can control the stereochemistry, regioselectivity and chemoselectivity. This builds on the Part II A2 course *The Foundations of Organic Synthesis* and considers more challenging synthetic targets (several stereocentres, highly functionalised, multiple rings, etc.), where retrosynthetic analysis combined with efficient synthetic methods are exploited to allow a high level of control in the execution of the synthesis. In addition to A2, it is usual to have done the part II courses B2 and C5 before starting M5. The main emphasis of the first part of this course is to link stereochemistry with retrosynthetic analysis, strategic bond recognition and stereocontrolled reactions (both diastereoselective and enantioselective). Illustrative examples will be given throughout from partial and total syntheses of a variety of natural (and unnatural) products. The course then focusses on the reactivities of p-block elements and how these can be exploited to design selective transformations. The final section of the course comprises a detailed look at pericyclic reactions.

### Topics

Part I: strategies for stereocontrol  
Controlling and understanding relative and absolute stereochemistry in modern organic synthesis. Diastereoselective reactions of enantiomerically pure starting materials (chiral pool manipulation). Enantioselective synthesis using chiral reagents, substrates and auxiliaries.

Part II: reactions and mechanisms

The use of p-block elements in organic synthesis; Pericyclic reactions and the Woodward-Hoffmann rule.

### Recommended books

*Organic Chemistry*, J. Clayden, N. Greeves, S. Warren, OUP 2012 (the first edition, OUP 2001, is also suitable) [QD251.O74]

*Classics in Total Synthesis*, K. C. Nicolaou, E. J. Sorensen, Wiley-VCH 1996. [QD262.N53]

### Further reading/reference

*Classics in Total Synthesis, Part II*, K. C. Nicolaou, S. Snyder, VCH, 2003. [QD262.N53]

*Classics in Total Synthesis, Part III*, K. C. Nicolaou, S. Snyder, VCH, 2011. [QD262.N53]

*Organic Chemistry*, J. Clayden, N. Greeves, S. Warren, P. Wothers, , OUP, 2000. [QD251.O74]

*Stereochemistry of Organic Compounds* E. L. Eliel, S. H. Wilen, L. N. Mander, , Chapter 12, Wiley, 1994. [QD481.E45]

*The Logic of Chemical Synthesis*, E. J. Corey, X.-M. Cheng, Wiley, 1989. [QD262.C67]

*Selected Organic Syntheses* I. Fleming, Wiley, 1973. [QD262.F54]

*Organic Synthesis*, J. FuhrHop, G. Penzlin, , 2nd Edn, VCH, 1994. [QD262.F84]

*Stereoselectivity in Organic Synthesis*, G. Procter, Oxford Chemistry Primer, OUP, 1998.

*Pericyclic Reactions*, Fleming, I.,, Oxford Chemistry Primer 67, OUP, 1998. [QD281.R5.F54]

## M6: Computer simulation methods in chemistry and physics

*Dr Jorge Espinosa (3 lectures), Dr Jerelle Joseph (3 lectures)  
and Dr Rosana Collepardo (6 lectures)*

In the last few decades computer simulations have emerged as a new scientific methodology – sandwiched between mathematical theories and experiment – with applications across the sciences and engineering. Because the parameters can be carefully controlled, these “theoretical experiments” provide powerful ways to develop fundamental understanding of the connection between microscopic models of the interactions between atoms and molecules and observable properties of many-particle systems.

This course is an introduction to the two basic simulation techniques, namely molecular dynamics, in which the equations of motion are solved step by step, and Monte Carlo, in which configuration space is explored by a series of “smart” random steps. We will emphasise the basic techniques and their statistical mechanical origins instead of attempting to cover the vast array of special tools now available. Knowledge of computer language or programming skills are not required. Instead, concepts will be detailed in “pseudocode”, describing the steps involved in setting up a simulation for simple model systems.

**Topics Molecular Dynamics basics:** Verlet algorithm, time and ensemble averages, temperature scaling, force calculation under periodic boundary conditions.

**Monte Carlo Basics:** Importance sampling, Metropolis algorithm.

**Calculation of properties of a system:** radial distribution function, virial pressure, velocity autocorrelation function.

**Advanced Monte Carlo methods:** Calculations in Different Ensembles, Biased Monte Carlo Simulations.

**Advanced molecular dynamics methods:** Temperature control using Nose thermostats, method of constraints.

**Equilibrium and Non-Equilibrium Processes:** Free Energy Calculations, Simulations of Phase Equilibria, Simulations of Non-Equilibrium Processes.

### **Recommended books**

*Understanding Molecular Simulation, From Algorithms to Applications*, D. Frenkel and B. Smit, (Academic Press). [QD461.F72]

*Computer Simulation of Liquids*, M. P. Allen and D. J. Tildesley (Clarendon Press). [QC145.2.A45]

*Introduction to Modern Statistical Mechanics*, D. Chandler (Oxford University Press). [QC174.8.C43]

*Molecular Modelling, Principles and Applications*, A. R. Leach (Longman). [QD480.L43]

## M8: Main group organometallics

*Dr Andrew Wheatley (6 lectures) and Dr Robert Less (6 lectures)*

Many main group metallated organic compounds find applications both as large-scale industrial chemicals and as important reagents in organic syntheses. This course will examine in detail the fundamental chemistries of main group organometallics. Modern bonding theories will be used to describe the interactions they form and to explain the diversity of their structures. The extent to which electron counting schemes can rationalise the structures of these molecules will be a common theme.

Students will benefit from having done *Inorganic I: Structure and Bonding* (Course A1) in Part II.

**Topics** s-block metals – Synthesis, structure and bonding of systems containing s-block metals, especially lithium, with organic ligands. The concepts of ‘ring stacking’ and ‘ring laddering’ will be used to rationalise and predict structures. Recent developments in the chemistry of heterobimetallic reagents (ate complexes) will be introduced. Reactions and selectivity will be

discussed, as will techniques for the elucidation of structures in the solid state and also in solution.

p-block metals – The greater covalency in compounds of p-block elements, compared to s-block elements, is manifested in the structures of the organometallics. Particular interest will be devoted to compounds formed from metals in low oxidation states and the unusual structures they form. The bonding and shapes of main group metallocenes are contrasted with those of the d-block, and the ability of p-block metals to act as ligands to transition metals is discussed.

Supervision arrangements: this course will be taught through *examples classes only*.

### **Recommended reading for Dr Wheatley's lectures**

*Structures of organonitrogen-lithium compounds*, K. Gregory, P. v. R Schleyer, R. Snaith, *Advances in Inorganic Chemistry*, 1991, **37**, 47(review).

*New avenues in the directed deprotometallation of aromatics: recent advances in directed cupration*, P.J. Hartford, A.J. Peel, F. Chavalier, R. Takita, F. Mongin, M. Uchiyama, A.E.H. Wheatley, *Dalton Trans.*, 2014, **43**, 14181 (Review).

*Ligand effects in the formation of tertiary carbanions from substituted tertiary aromatic amides*, A.C Smith, M. Donnard, J. Haywood, M. McPartlin, M.A. Vincent, I.H. Hillier, J. Clayden, A.E.H. Wheatley, *Chem. Eur. J.*, 2011, **17**, 8078.

*Deprotonative metalation using ate compounds: synergy, synthesis, and structure building*, R.E. Mulvey, F. Mongin, M. Uchiyama, Y. Kondo, *Angew. Chem. Int. Ed.*, 2007, **46**, 3802 (review).

### **Reference material for p-block organometallics**

*Organometallics*, C. Elschenbroich, (Wiley). [QD411.E47]

*Chemistry of the Elements*, N. N. Greenwood, A. Earnshaw, (Elsevier) [QD466.G74]

## **M9: Aromatic heterocycles and medicinal chemistry**

*Dr Stephanie Smith*

It is estimated that 2/3 of all known compounds are aromatic heterocycles: molecules with cyclic delocalised  $\pi$  systems like that of benzene but incorporating one or more heteroatoms such as nitrogen, oxygen or sulfur into the ring in place of carbon. The introduction of such atoms has a significant effect on the reactivity of these molecules, as well as opening the door to a range of synthetic methods, and in this course we will examine some of the rich chemistry of aromatic heterocycles and investigate how such molecules can be synthesised.

Aromatic heterocycles feature strongly in medicinal chemistry, with many top-selling drugs being based on or containing a heteroaromatic ring. The pharmaceutical industry is one of the major employers of organic chemistry graduates, and the last part of this course gives an overview of modern drug discovery, development and production, illustrated with a number of case studies.

This is an organic chemistry course with a strong focus on reaction mechanisms and no prior knowledge of biochemistry is required. Usually, students that do this course will have done the following courses in Part II: A2 *The foundations of organic synthesis*; B2 *Structure and reactivity*; C5: *Control in organic chemistry*.

**Topics** Structure and reactivity of aromatic heterocycles: pyridines and pyridones, quinolines and isoquinolines, pyrroles, furans, thiophenes and indoles, diazines, diazoles, triazoles and tetrazoles.

Synthesis of aromatic heterocycles.

The drug discovery process: lead identification, drug optimisation, and drug production.

There will also be the chance to hear about process chemistry through a lecture by Dr Sabine Fenner, currently working in this area at GSK.

## **Recommended Books**

### **[Earlier editions will also suffice]**

*Organic Chemistry*, Clayden, J., Greeves, N. and Warren, S., OUP, 2nd Edn. 2012 (Ch. 29 and 30). [QD251.O74]

*Heterocyclic Chemistry at a Glance*, Joule, J.A. and Mills, K., Blackwell Publishing, 2nd Edn. 2013. [QD400.J68]

*Aromatic Heterocyclic Chemistry*, Davies, D.T., Oxford Chemistry Primers, OUP, 1992. [QD400.D38]

*An Introduction to Medicinal Chemistry*, Patrick, G.L., OUP, 6th Edn. 2017. [RS403.P38]

## **For reference**

### **[Earlier editions will also suffice]**

*The Chemistry of Heterocycles: Structure, Reactions, Synthesis and Applications*, Eicher, T., Hauptmann, S. and Speicher, A. Wiley-VCH, 3rd Edn. 2012. [QD400.E43]

*Heterocyclic Chemistry*, Joule, J.A. and Mills, K., Wiley, 5th Edn. 2010. [QD400.J68]

*Top Drugs, Top Synthetic Routes*, Saunders, J. Oxford Chemistry Primers, OUP, 2000. [R403.S28]

*Process Development: Fine Chemicals from Grams to Kilograms*, Lee, S. and Robinson, G., Oxford Chemistry Primers, OUP, 1995. [RS403.L33]

*Foye's Principles of Medicinal Chemistry*, Williams, D. A. and Lemke, T. L., Lippincott, Williams and Wilkins, 7th Edn. 2013. [RS403.F69]

Part III Chemists are permitted to take up to *two* of these interdisciplinary courses, substituting them for the Lent Term chemistry courses.

## **I1: Atmospheric chemistry and global change**

This course is hosted by and based in the Department of Chemistry.

*Prof. John Pyle and others*

This course looks at global change from the perspective of atmospheric composition and its linkage to the climate system. Issues covered include the fundamental photochemical and dynamical processes which control atmospheric composition and structure, and how they would differ in a modified climate. The course is designed to complement the material covered in Course I2 *The Earth System and Climate Change*, although either course can be taken independently. The course will be lectured and examined in a way that assumes no prior knowledge for those taking the course.

### **Core lectures (12)**

Atmospheric composition and structure. Stratospheric and tropospheric chemical processes. Climate change.

Major stratospheric catalytic cycles of NO<sub>x</sub>, HO<sub>x</sub>, ClO<sub>x</sub> and BrO<sub>x</sub>. Atmospheric aerosol and their role in cloud microphysics and radiative forcing of climate. Ozone depletion in the Antarctic, Arctic and middle latitudes. Future O<sub>3</sub> trends.

Tropospheric ozone and tropospheric oxidation processes, including the importance of the OH radical. The ozone balance - the role of NO<sub>x</sub> and hydrocarbons.

Greenhouse gases. Radiative balance. Climate change and the links between atmospheric chemistry and climate.

### **Recommended books**

R. P. Wayne, *Chemistry of Atmospheres*, Third Edition (2000), OUP. [QC879.6.W39]

G. P. Brasseur, J. J. Orlando and G. S. Tyndall, *Atmospheric Chemistry and Global Change*, (1999), OUP. [QC879.6.A86]

T. E. Graedel and P. J. Crutzen, *Atmospheric Change - An Earth System Perspective*, (1993) W. H. Freeman and Co (New York). [QC981.8.G73]

B. J. Finlayson-Pitts and J. N. Pitts, Jr *Chemistry of the upper and lower atmosphere*, Academic Press. [QC879.6.F56]

D. J. Jacob, *Introduction to Atmospheric Chemistry*, (2004) Princeton University Press. [QC879.6.J33]

The following two items contains useful introductory material

J. T. Houghton, *Global warming, the complete briefing*, (2004), CUP. [QC981.8.G56.H68]

<http://www.ipcc.ch> International Panel on Climate Change.

## I2: The Earth System and Climate change

This course is hosted by and based in the Department of Earth Sciences.

### **This course will assume a knowledge of Part IA NST Earth Sciences**

Students who have had no prior Earth Science education are welcome to contact the lecturer for reading and background material before the course starts.

*Dr Luke Skinner and Prof. Eric Wolff*

### **16 1-hour lectures**

Lectures will be held on Tuesday and Thursday mornings (10-11 am). Some of these lectures will include a practical element, generally making use of simple computer code and mathematical models. The course is broken up broadly into three parts:

- To provide some background on the 'big climate questions', as well as the broad sweep of Earth's climate history
- An overview of the key climate components and how they can be represented in simple models
- Case studies in past climate change, that illustrate both fast- and slow dynamics in the Earth's climate system

The course aims ultimately to provide a long-term 'systems perspective' on future climate change.

## I3: Materials, electronics and renewable energy

This course is hosted by and based in the Department of Physics. Lectures will be at 12:15 to allow for travelling time from other departments.

*Dr Siân Dutton and Dr Akshay Rao*

This interdisciplinary course looks at the physical concepts and challenges concerning energy generation, storage and use. The course aims to develop knowledge of the basic physical principles governing renewable energy materials and devices. It will develop skills in using simple quantitative estimates for a wide range of renewable energy problems to give a fact-based approach the energy questions.

Only IA-level physics is a prerequisite; those who have experience of solid-state physics will find some parts of the course more straightforward, but the material will be taught and examined such that no prior knowledge in this area is required.

**Energy requirements and energy use** Energy cost of transport of people and freight. Exergy and exergy efficiency. Lighting. Computing.

**Alternatives to fossil fuels** Intro to the science of climate change. Availability of renewable energy. nuclear, wind, geothermal, solar, wave, tide — scale required. Energy density: Petrol, coal, biofuel, hydro, nuclear.

**Energy Transmission** AC vs DC electricity. Pipelines. Heat engines, heat pumps, ACs.

**Semiconductor Crash Course** Semiconductor electronic structure. Tight-binding band structure. Optical properties (direct and indirect gaps, excitons). Interaction with light. Excitons. Electrons and holes. Doping.

**Solar Energy–1: How nature powers the biosphere** Structure and optoelectronic operation. Charge separation and recombination. Efficiency. Solar Fuels including hydrogen

**Solar Energy–2: Manufactured solutions** Solar concentration. Solar thermal. The p-n junction. PV devices operation.

**Solar Energy–3: Next generation technologies** Electrical properties; silicon, III-V semiconductors, 2D semiconductors and heterostructures. Si, Perovskites, III-Vs. Tandems, MEG etc.

**Electrochemistry Crash Course** Galvanic cells and electrodes. Half and full cell reactions. Charge transport. Potentials and thermodynamics — relationship to structure.

**Energy Storage–1** Requirements and specifications. Metrics – energy density, power density, rate capacity. Fly wheels, pumped, electrochemical, chemical and comparison with fossil fuels and back of the envelope calculations.

**Energy Storage–2** Electrochemical energy storage. Batteries – lead acid, Li-ion and beyond. Supercapacitors.

**Energy Storage–3** Fuel cells. principles of operation, materials challenges. Hydrogen storage, materials challenges. Hydrogen vs. electric vehicles.

### **Recommended books**

*Sustainable Energy – Without the Hot Air*, Mackay D. J. C. UIT : Cambridge (2009) [TJ808.M33]

*The Physics of Solar Cells*, Nelson J. Imperial College Press (2003) [QC715.4.N45]

*Molecular Mechanisms of Photosynthesis*, Blankenship R. E. Blackwell Science (2002) [QK882.B53]

*Modern Batteries*, Colin Vincent and Bruno Scrosati, Arnold, 2nd Edition (1997)

## L1: Catalysis in synthesis

*Dr Robert Phipps*

This course introduces the important role of catalysis in organic synthesis. The first half will deal with transition metal catalysis and will cover fundamental mechanisms of transition metal complexes and conceptually relevant stoichiometric advances before moving onto the main body of the material dealing with cross-coupling reactions and metathesis processes. The second part will introduce enantioselective catalysis and will cover topics such as enantioselective oxidation and reduction of simple organic molecules, C–C bond forming reactions with chiral Lewis acid catalysis as well as covering more recent advances in organocatalysis. A specific objective of this course is to illustrate how concepts in asymmetric and transition metal catalysis can be used to routinely applied to construct natural products and medicinal compounds.

### **Recommended books**

*Transition metals in the synthesis of complex organic molecules*, Louis S. Hegedus, University Science Books, 2009. [QD262.H44]

*Organic Synthesis Using Transition Metals*, Roderick Bates, Wiley, 2012. (Available as eBook downloadable from University Network. DOI: 10.1002/9781119942863) [QD172.T6.B38]

*Organotransition metal chemistry: from bonding to catalysis*, John F. Hartwig, University Science Books, 2010. [QD411.8.T73.H37]

*Fundamentals of Asymmetric Catalysis*, Patrick J. Walsh and Marisa C. Kozlowski., University Science Books, 2008. [QD505.W35]

*New Frontiers in Asymmetric Catalysis*, Wiley, 2007. (Available as eBook downloadable from University Network. DOI: 10.1002/0470098007)

*Catalytic Asymmetric Synthesis*, I Ojima (Ed.), Wiley, 2010. (Available as eBook downloadable from University Network. DOI: 10.1002/9780470584248) [QD262.C38]

## L3: Electronic structure of solid surfaces

*Prof. Stephen Jenkins*

**PLEASE NOTE:** For 2021/22 this course will be using recorded lectures which will be released according to the advertised schedule.

The surface of a solid material is of crucial importance in its interaction with the outside world. This is the location where molecules from the surrounding gas or liquid can modify the chemistry of the solid (e.g. corrosion) and equally where the solid can influence the chemistry of external molecules (e.g. catalysis). Furthermore, the physical properties of solid surfaces are often rather different from those of the parent bulk material (e.g. surface-localised electronic or magnetic phenomena) and these differences can often be critical in a variety of practical applications.

This course will examine the nature of solid surfaces, with a particular focus on their electronic structure. Not only will it cover the inherent electronic properties of surfaces themselves, but it will also describe the chemisorption of atoms and molecules via ionic and covalent interactions. A variety of experimental techniques capable of probing surface electronic structure will also be discussed.

**Topics** Surfaces of face-centred cubic and body-centred cubic materials

Friedel oscillations, surface dipole and work function

Ultra-violet Photoemission Spectroscopy (UPS); X-ray Photoemission Spectroscopy (XPS)

Inverse Photoemission Spectroscopy (IPES); Auger Electron Spectroscopy (AES)



Near-Edge X-ray Absorption Fine Structure (NEXAFS)  
Frontier-Orbital description of chemisorption: ionic and covalent adsorption  
Surface-localised electronic states: Shockley, Tamm and Image states  
Scattering of Shockley states from surface steps  
Itinerant ferromagnetism in bulk solids and at their surfaces  
Surface-enhanced and surface-induced ferromagnetism  
Adsorbate-induced quenching of ferromagnetism

### **Recommended books**

A. Zangwill, *Physics at Surfaces*, Cambridge University Press, 1988 [QC173.4.S94.Z36]  
D.P. Woodruff and T.A. Delchar, *Modern Techniques of Surface Science*, Cambridge University Press, 1994 [QC173.4.S94.W66]  
G. Attard and C. Barnes, *Surfaces*, Oxford University Press, 1998 [QD506.A88]  
J.A. Venables, *Introduction to Surface and Thin-Film Processes*, Cambridge University Press, 2000 [QC176.83.V46]  
G.A. Somorjai and Y. Li, *Introduction to Surface Chemistry and Catalysis*, Wiley-Blackwell, 2010 [QD506.S66]

## **L4: Chemical biology and drug discovery**

*Dr Gonalo Bernardes (6 lectures) and Dr Anthony Coyne (6 lectures)*

Our understanding of biological processes at the molecular level is developing at an unprecedented rate. Advances in genomics and proteomics, coupled with a rapid increase in the amount of structural information about proteins, are providing a wealth of information about the interaction between a protein and its ligand. In this course we will use some key biological systems to explain ideas about the interplay between structure, function and inhibition in chemical biology. We will also highlight chemical strategies that allow for site-selective protein modification and how these are being used to provide biological insight and for the construction of protein conjugates for therapeutics. Finally, we will discuss the science behind the different approaches adopted by academia and the pharmaceutical industry in the early stages of drug discovery. The course builds on material in the Part II course on *Biological Catalysis* (B3).

**Topics** Mechanisms of enzyme inhibition, key concepts, oligosaccharide chemistry, radical reactions on enzymes, post-translational modification of proteins, kinases, HTS, fragment based approaches to enzyme inhibition

Site-selective protein modification chemistry - strategies and mechanisms; examples of its use to the understanding of basic biology and protein therapeutics

### **Recommended books**

General

*An introduction to enzyme and coenzyme chemistry*, T. D. H. Bugg, Blackwell 2004 [QP601.B84]

*Medicinal chemistry, principles and practice*, Ed. F. D. King, RSC 2002 [RS403.M43]

*The organic chemistry of enzyme-catalysed reactions*, R. B. Silverman, Academic Press, 2000 [QP601.S55]

*Bioconjugate Techniques* (Third Edition) by Greg T. Hermanson, Academic press [On Order]

More specialized

*Evaluation of enzyme inhibitors in drug discovery*, R. A. Copeland, Wiley 2005 [QP601.5.C67]

*Posttranslational modification of proteins*, C. T. Walsh, Roberts 2006 [QH450.6.W35]

*Fragment based approaches in drug discovery*, Ed. W. Jahnke, D. A. Erlanson, Wiley VCH 2006 [RM301.25.F73]

## L5: Solid electrolytes

*Prof. Stephen Elliott (6 lectures) and Dr Sergei Taraskin (6 lectures)*

This course is concerned with the motion of ions through solids, and it builds upon material given in the IB course *Electronic Structure and Properties of Solids*.

Ions can move between sites only in defective solids: an introduction is therefore given of the types of disorder and the nature of defects that can occur in solids. A detailed description will be given of various aspects of ionic motion in solids: this relates to topics such as percolation, random walks on lattices, phase transformations, fractals etc. Experimental techniques for obtaining information about ionic transport in materials, such as electrical conductivity, radioactive-tracer diffusion, NMR and quasielastic neutron scattering, will be introduced. Finally, a discussion will be given of the various applications of ionically-conducting materials, including solid-state batteries, ion sensors and fuel cells.

**Topics** Structure of crystalline and disordered materials. Models and behaviour of defects in solids. The basics of diffusion. Examples of fast ion conductors: structure and transport properties. Models of ionic motion in solid electrolytes. Linear response theory: conductivity and diffusion. Lattice models for diffusion: mean-field approaches. Experimental probes of ionic diffusion. A.C. conductivity and percolation. Applications of solid electrolytes.

### Recommended books

*Basic Solid State Chemistry*, 2nd ed, A.R. West, Wiley, 1999. [QD478.W47]  
*The Physical Chemistry of Solids*, R.J. Borg and G.J. Dienes, Academic, 1992. [QD478.B67]  
*Physics and Chemistry of Solids*. S.R. Elliott, Wiley, 1998. [QC176.5.E45]  
*Solid State Electrochemistry*, ed. P.G. Bruce, CUP, 1995. [QD454.H36]  
*Elements of the Random Walk*, J. Rudnick and G. Gasperi, CUP, 2004. [QA274.73.R83]  
*Hopping Conduction in Solids*, H. Bottger and V. Bryskin, VCH, 1986. [QC176.H66.B68]  
*Atomic Transport in Solids*, A.R. Allnatt and A.B. Lidiard, CUP, 1993. [QC176.8.E4.A45]

## L6: Supramolecular chemistry and self-organisation

*Prof. Jonathan Nitschke*

Physical laws can direct the flow of matter toward a more organised state. One particular strand of matter that began to organise itself chemically over 3 billion years ago started down the road to Darwinian evolution, eventually leading to the emergence of multicellular organisms such as the one reading this text. This course covers fundamental aspects and selected recent advances in the broad area of synthetic self-organising chemical systems and supramolecular chemistry.

Prerequisites include a good working knowledge of basic organic chemistry and coordination chemistry, as well as NMR spectroscopy.

1–6 **Fundamentals.** Thinking “beyond the molecule” – the sense behind “supramolecular”. Thermodynamics and equilibria. Structural and spectroscopic characterisation methods for large and complex architectures. Non-covalent interactions: hydrogen bonding, metal-ligand, aromatic ( $\pi - \pi$ ), cation –  $\pi$ , van der Waals, donor–acceptor. Dynamic covalent linkages. Building blocks, host-guest chemistry. Dynamic combinatorial chemistry

7–12 **Complexity and Function.** Molecular topology and entanglements. Molecular machines, energy transduction. Molecular switches and sensors. Maxwell’s Demon, summoned. Reactions within container molecules and supramolecular catalysis. Self-replication. Supramolecular polymers. The emergence of complexity. The interface with biology.

### Recommended Books

*Modern Physical Organic Chemistry*, E. V. Anslyn and D. A. Dougherty, University Science Books, 2006. [QD476.A57]  
*Supramolecular Chemistry*, P. D. Beer, P. A. Gale and D. K. Smith, Oxford Chemistry Primer, OUP 1999. [[QD381.B44]  
*Supramolecular Chemistry*, J. W. Steed and J. L. Atwood, Wiley, 2000. [QD878.S74]  
*Principles and methods in supramolecular chemistry*, H. J. Schneider and A. Yatsimirski, Wiley, 1999. [QD878.S36]

## L7: Chemical dynamics and machine learning

*Prof. Stuart Althorpe (6 lectures), Dr Lucy Colwell (3 lectures) and Prof. David Wales (3 lectures)*

**PLEASE NOTE:** For 2021/22 the course order will be ML then Chemical dynamics

### Chemical dynamics

The general objective of chemical dynamics is explaining the rates of chemical reactions in terms of a microscopic mechanism. More specifically, one aims to compute the rate starting from first principles classical or quantum mechanics. This is the subject of this course. The course is divided in two parts, chemical dynamics in the gas phase (SC) and in solution (MS).

To predict a rate exactly one must calculate the wave function describing the motion of the atoms during the reaction. We explain the general nature of such wave functions and how they may be calculated accurately for simple gas-phase reactions. We then explain how to approximate this dynamics using Newtonian mechanics, or a combination of Newtonian and quantum mechanics, so as to include quantum tunnelling and zero point energy effects. This leads us to a rigorous derivation of transition state theory, which provides a simple unifying explanation of many chemical reactions. We also discuss when transition state theory fails.

The central concept in the solution chemistry part of the course is again transition state theory, how this theory can be derived for a condensed phase environment and how it can be used to understand solvent effects on reaction rates. We will also examine situations where transition theory breaks down and derive more general equations for reaction rates. The key theoretical tool for this part of the course is classical statistical mechanics. Quantum effects, although they can be important, will not be considered.

### Machine Learning

In this part of the course we will apply the theory and computational procedures developed for molecular energy landscapes to the loss function defined by a neural network. First, the energy landscape approach will be summarised, including an overview of global optimisation and geometry optimisation procedures for constructing stationary point databases. The loss function associated with training a neural network will then be defined, along with the area under curve performance measure. Thermodynamic analogues will then be introduced, followed by notation for networks with multiple hidden layers.

Examples of loss function landscapes will then be described for a classification problem in molecular geometry optimisation and prediction of patient outcomes from electronic health records.

Required Part II course: *Statistical Mechanics* (B6).

**Topics** Reaction dynamics: atomic motion on the femtosecond timescale.

The wave functions of gas-phase reactions: introduction to quantum scattering theory.

Classical theory of rates and classical transition state theory.

Quantum corrections to transition state theory: the effect of tunnelling on reaction rates.

When transition state theory fails.

Some observations about reactions in solution relaxation and correlations in linear response theory.

Transition state theory in the condensed phase, from potential energy surfaces to potentials of mean force.

Diffusion, mobility and friction, Stokes Einstein relation.

### **Recommended Books**

*Theories of Molecular Reaction Dynamics*, Niels E. Henriksen and Flemming Y. Hansen, Oxford University Press. [QP517.M65.H46]

*Introduction to Modern Statistical Mechanics*, David Chandler, Oxford University Press. [QC174.8.C43]

## **L8: Total synthesis**

*Prof. Matthew Gaunt*

This course will deal with strategy and design in the total synthesis of natural products and medicines. The lectures will draw together the principles of many of the other synthetic chemistry lecture courses to illustrate how they can be combined in complex molecules applications.

The course will take a concept driven approach to how complex molecules can be synthesised, addressing aspects of chemical reactivity, catalysis, ring forming reactions, protecting groups, inter- and intramolecular reactions, tandem and cascade processes, and multi-component reactions. These topics will be illustrated with real examples of total synthesis. A key aim of this course will be to teach the design principles that underpin the synthesis of complex molecules.

**Previous course requirements.** All Part II and Michaelmas term Part III synthetic chemistry courses would be helpful.

### **Recommended reading**

*The Logic of Chemical Synthesis*, Corey, E. J. and Cheng, X.-M., Wiley, 1989. [QD262.C67]

*Classis in Total Synthesis*, K. C. Nicolaou, VCH, 1996. [QD262.N53]

*Comprehensive Organic Transformations: A Guide to Functional Group Preparations*, R. C. Larock, Wiley VCH, 1999. [QD262.L37]

*Tactics in Organic Synthesis*, T. L. Ho, Wiley, 1994. [QD262.H6]

*Organic Synthesis: The Disconnection Approach*, S. Warren, 1982. [QD262.W93]

## **L9: Biosynthesis**

*Dr Finian Leeper*

Organisms make a vast range of chemical compounds and a great number of these natural products, or compounds derived from them, have been used as medicines. Their great importance to humans has motivated organic chemists to determine their structure, synthesise them and elucidate how they are formed by the producing organism. Despite their great diversity, most natural products are derived by way of one or more of a handful of biosynthetic pathways. This course highlights their common origin from simple building blocks (e.g. acetate or one of the amino acids) and details key reactions involved in their biosynthesis. Examples will be taken from polyketide beta-lactam and glycopeptide antibiotics, terpenes and alkaloids (e.g. cocaine) which are widely used (and abused).

### **Recommended books**

Dewick P. M., *Medicinal Natural Products: A Biosynthetic Approach*, 3rd edition, Wiley, 2009. [RS160.D49]

McMurry J. E. and Begley T.P., *The Organic Chemistry of Biological Pathways*, Roberts and Co., 2005. [QP550.M36]

Walsh C. *Antibiotics: Actions, Origins, Resistance*, ASM Press, 2003. [RM267.W35]

Walsh C.T and Tang Y., *Natural Product Biosynthesis: Chemical Logic and Enzymatic Machinery*, RSC, 2017

### *Duration and pattern of work*

You may start work on your project at the beginning of the Michaelmas Term, although it will of course be up to your supervisor to set the programme of work. You may not start any experimental work until you have attended the Departmental safety talk.

The number of hours that you will need to be in the laboratory working on your project will depend on the nature of the research you are doing – some projects will require most of the time to be spent ‘at the bench’, while others may involve devoting significant amounts of time learning background theory or mastering new skills. You may find that the pattern of work is uneven, too: for example, you may have a very intensive period of taking data, followed by a longer period of digesting and analysing your measurements. You may also find that at times your progress is held up while you wait for equipment or analytical services. You will need to be flexible in your approach.

We expect that most mornings you will have several lectures to attend, and as a result although you may have the odd hour to devote to your project, it will not be possible to get down to concentrated work. The main work on the project will therefore be in the afternoons, and as a norm we suggest that you devote about four afternoons per week to your project.

You will have work for supervisions to prepare and supervisions to attend. This, along with attendance at lectures, should take priority over work on your project.

### *Supervision and safe working*

Your supervisor will be the member of the academic staff in whose group you are working and he or she will be responsible for the direction of your work and for ensuring safe working. The day to day supervision of your work may be delegated to another member of the research group.

If you have any doubt about how to proceed or about the safety of any experimental procedure you should stop work immediately and seek advice from your supervisor. It is your responsibility to ensure that you comply with any safety instructions given and follow the procedures set out for you. Safety is your responsibility.

### *Laboratory hours*

Normal working hours are 09:00 – 17:00, weekdays *during Full Term*. You may undertake experimental work outside these hours only in exceptional circumstances determined by your supervisor. Work outside these normal hours you must be under the continuous and direct supervision of your supervisor or another senior person delegated by him or her.

Experimental work during the Christmas and Easter vacations is *expressly forbidden*. The only exception to this is where work during the term has been significantly disrupted, in which case permission may be given for limited work during the vacation. Your project supervisor should contact the Director of Teaching to arrange this.

### *Assessment*

The dissertation will only count 35% towards your final mark. You should bear this in mind when allocating your time between the project, lectures, supervision work and so on.

The project will be assessed not on the basis of the results you obtain, but on your input to and commitment to the project, the progress you have made and how much you have contributed to this, the analysis and presentation of your work. Details of the assessment procedure is given below.

## *Monitoring progress*

Your supervisor will be responsible for monitoring your progress. If, however, you feel concerned about your progress you should not hesitate to contact your Director of Studies, the Director of Teaching or the members of staff designated to oversee projects in your area (Inorganic: Dr Sally Boss; Organic: Dr Bill Nolan; Physical: Dr James Keeler). It is particularly important that you do not spend too much time on the project, and if you feel that you are being pressurized into doing this you should seek advice.

## *Presentation of the dissertation*

The dissertation should not exceed 5000 words in length, excluding the abstract, figure captions, footnotes, table of contents, references and acknowledgements; experimental details are, for these purposes, classified as footnotes.

The dissertation should be typed or word processed and sufficient margins should be used such that the text is easily readable i.e. it does not get lost into the binding edge. The dissertation should either be spiral bound or bound in a soft cover; loose-leaf or ring binders are not acceptable.

The dissertation should have (in this order): a title page, the signed declaration (see below), acknowledgements, a one-page summary of the dissertation (an abstract), a table of contents. The main text then follows. You may place literature references at the end of each chapter or at the end of the main text.

Figures, tables and schemes should be numbered so that they can be referred to easily; it is usual to give captions to figures. References should be indicated by superscript numerals or numerals in brackets. Pages should be numbered sequentially.

Your dissertation should contain the following declaration, which you should sign and date in each copy.

*This dissertation is submitted in partial fulfilment of the requirements for Part III Chemistry. It describes work carried out in the Department of Chemistry in the Michaelmas Term 2021 and the Lent Term 2022. Unless otherwise indicated, the research described is my own and not the product of collaboration.*

## *What should be in the Dissertation*

The details of what to write up and how to go about it vary very much from subject to subject; you supervisor will advise on this. However, in general a dissertation ought to contain:

- An introduction, describing what you set out to do and how this fits into the 'bigger picture'. You should address the question as to why it was important to work on this topic.
- Some background discussion (perhaps also background theory) setting out the framework in which your work was done, establishing the language you are going to use, and describing the 'prior art'.
- A description of your work, taking care to make the underlying logic plain, how each experiment was conceived and executed; results and interpretation of results; significance of the results.
- A conclusion, setting out the achievements, their significance, and possibly suggesting directions for future work.

All this needs to be illustrated with appropriate figures, tables and schemes.

## Style

Traditionally, scientific papers and theses are written in the impersonal voice e.g. 'an experiment was developed' rather than 'I developed an experiment'. Some people use 'we', but this can irritate after a while if it is used excessively; sparing use of this construction is probably acceptable. Never use I – it sounds vain and pompous. Addressing the reader as 'you' is not appropriate in a dissertation. Generally you should aim for good plain English, avoiding the temptation for jokiness or informality.

You can get a good idea of the usual typographic conventions by looking at papers and books published in the area you are working in. Here is a list of some key points to look out for

1. Chemical formulae are printed in a roman (upright) type face and not in italic e.g.  $\text{H}_2\text{O}$  and not *H<sub>2</sub>O*. The state, if needed, is also given in roman e.g.  $\text{H}_2\text{O}(\text{g})$  and not *H<sub>2</sub>O(g)*.
2. In mathematical expressions it is normal to use italic for variables, but a roman type face for the names of functions and numbers e.g.  $\sin(2x)$  and not *sin(2x)* nor *sin(2x)*. The number e and the complex i are numbers and so are set in roman e.g.  $e^x$  and  $\exp(i\theta)$ . In integrals, the variable of integration is indicated with the 'd' in roman e.g.  $dx$  and not *dx*.
3. Units are given in roman e.g.  $\text{mol dm}^{-3}$  and not *mol dm<sup>-3</sup>*. Be sure to leave a *space* between the number and the unit, and also leave spaces between each unit e.g. 3.0 s *not* 3.0s;  $\text{mol dm}^{-3}$  *not*  $\text{mol dm}^{-3}$ .
4. If using exponent notation be careful to set the number out clearly, using spaces and the correct multiplication symbol  $\times$  rather than 'x' or 'X' e.g.  $3.1 \times 10^{-4}$  and *not* 3.1E-4 *nor* 3.1x10(-4)

## References

It is important to give correct and appropriate references to the scientific literature or published books throughout your dissertation. Generally speaking it is *not* appropriate to cite web sites as a source of information unless these are repositories of information or data maintained by a learned society or other official body; similarly, you should not cite unpublished lecture notes.

## Experimental section

An important part of your dissertation is that it should contain sufficient details of how you performed your experiments so as to enable someone else in the field to repeat your work. In synthetic chemistry it is also important to give all of the details as to how you characterised your compounds e.g. NMR data. The conventions as to how these data are presented vary somewhat, but it is common to gather the data together in an 'Experimental Section'.

You should find out what the conventions are in the area in which you are working and then make sure that your dissertation conforms with these conventions. A poor or incomplete experimental section will result in the loss of marks in the assessment.

## Diagrams and schemes

Diagrams and schemes should be numbered, and you will probably want to use a short figure caption for the diagrams. All diagrams and schemes *must* be referred to in the text: i.e. you cannot have a 'Fig. 10' to which no reference is ever made in the text.

Modern technology makes it easy to 'rip off' diagrams from books, web pages, papers and other people's dissertations or theses. It is only acceptable to do this *if* you make the source of the diagram entirely clear by making an *explicit statement* to that effect in the caption e.g. 'figure taken from Bloggs 1999' or 'figure taken from reference 9'. It is not sufficient just to give a

reference in the caption – you must state explicitly that the figure is reproduced from that reference.

Ideally, you ought to obtain the author's permission to use the diagram, but as these Part III dissertations are not intended for direct publication it is not necessary – on this occasion – to obtain such permissions. If you are using a diagram from someone currently in your research group, it would be wise to ask permission.

Pay close attention to the legibility of diagrams, especially if they have been scanned in. It is all too common for Part III dissertations to contain diagrams which are essentially unreadable due to poor reproduction, particularly the lettering on scales.

In preparing graphs and tables, pay close attention to the advice you were given in the Part IB and II Physical laboratory. Common pitfalls are: poorly labelled axes, missing units, poorly chosen axes, numbers quoted with excessive precision on either axis labels or tabulated quantities.

### *Spelling, grammar and proof reading*

Do use the spell check facility that comes with the word processing package (most can be set to learn technical words). For each sentence you write you need to ask the question 'does it say what I meant it to say'? Too often, sentences at the first draft are ambiguous and open to several interpretations. In formal writing, it is not usual to use contractions (doesn't, can't, it's etc.).

Ideally, you need two kinds of person to read your work: one who knows what it is about, and so can advise on errors of fact or interpretation; one who does not know too much about the work and so will comment on the quality of the writing.

Please note that you cannot expect your supervisor or members of their research group to comment on multiple drafts of your dissertation. Your supervisor will, however, advise on the content and presentation of your work in broad terms.

### *Deadline for completion*

You are required to hand in **three** copies of your dissertation, two of which will be returned to you and one of which will be retained by your supervisor; you should also keep a copy for yourself. The deadline for handing in dissertations is the first Friday of Easter Full Term i.e. Friday 29th April. Dissertations should be handed in to Rafel Cabot Mesquida in the Part II Organic Teaching Lab.

You will also need to submit an electronic version of your dissertation to the *Turnitin* system, via Moodle. Details of how this can be done will be circulated nearer the time.

[www.plagiarism.admin.cam.ac.uk/turnitin-uk](http://www.plagiarism.admin.cam.ac.uk/turnitin-uk)

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## 9

### **Assessment of projects**

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The project will be assessed on the basis of your input to and commitment to the work, the progress you have made, and the way in which you present and explain your work, both in written and oral form. There are no specific marks awarded for the results you obtain.

Half of the marks for your project will be awarded by your supervisor (in consultation with your day-to-day supervisor, if there is one): these marks are for your commitment, competence, intellectual contribution, and your oral presentation. They are not related to the written dissertation.

The other half of the marks are assigned by one of the Part III Examiners together with another member of staff who is familiar with your area of work. This part of the assessment focuses on



the written project and your discussion of it in a short oral examination.

### *Interviews*

As part of the assessment process you will be called for an interview (of about 20 minutes duration) in which you can expect to be asked questions about your project, the conclusions you have drawn and the general area. The interview will be conducted by the two people who are assessing your written project.

These interviews will be held in the week beginning Monday 9th May.

### *Details of the marking procedure*

The marks are divided up into several categories. In each category, some questions are given which are intended to focus the assessors on relevant issues; these questions are simply indicative and are neither exclusive nor exhaustive. The Examiners may vary the marks awarded in each category: the marks given below indicative.

### **Marks awarded by the project supervisor in consultation with the day-to-day supervisor (if relevant)**

#### *Commitment (17 marks)*

- Did the student devote an appropriate amount of time to the project?
- Were they a willing worker or did they need to be 'chased' by their day-to-day supervisor?
- Did they take a wider interest in the work of the group and participate in relevant activities?
- Did they take the work seriously?
- Did they engage with/seek out relevant literature?

#### *Competence (17 marks)*

- Did the student have the expected skills on arrival?
- How quickly did they learn new skills and techniques?
- Were they a safe and reliable worker, or did they need close supervision?
- Were they able to interpret their results?
- Were they appropriately critical of their results?
- Were they able to work out the next steps?

#### *Intellectual contribution (10 marks)*

- Did the student simply follow the route set out for them or were they able to suggest or develop alternatives?
- When there were difficulties, were they able to develop their own solutions?
- Were they able to work out possible ways forward to take the project further?

#### *Oral presentation (6 marks)*

- Was the presentation well thought out and prepared?
- Did the student respond well to questions?

### **Marks awarded by the two assessors (one of the Examiners and another member of staff)**

#### *The presentation and content of the dissertation (30 marks)*

- Does the introduction set out the aims of the project?
- Is the prior art made clear, with appropriate references?
- Is it clear how the present work fits into the bigger scheme?
  
- Is the material organized in an appropriate order that makes the development of the ideas

and experiments easy to follow?

Does the writing convey a sense that the student understands the work? Are appropriate conclusions drawn?

Are there appropriate suggestions for future work?

How is the overall 'look' of the dissertation? Has it been well prepared? Are the diagrams and figures of an appropriate standard and used to good effect?

Is the written English clear, grammatical and of a good standard?

Is the description of the experimental work appropriate within the conventions of this kind of work?

*Interview (20 marks)*

Did the candidate appear to know about their own work and its context?

Were they able to answer questions in a convincing way?

Were they able to bring in related material?

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## 10 Supervision

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The arrangements of supervisions is the responsibility of your College, specifically your Director of Studies. However, given the specialized nature of the courses offered in Part III, the lecturers will suggest the names of suitable supervisors. If you require supervisions on a course, you should sign up on any lists provided – do not wait until the course is over before requesting supervisions.

It is not appropriate to have large numbers of supervisions for Part III courses. The relatively small number of people likely to be taking each course should enable the lectures to be more informal in style, giving the opportunity to ask questions and to raise points during or after lectures.

For some popular Part III courses it may be the case that there are insufficient supervisors available. Under these circumstances the lecturer(s) will arrange classes rather than supervisions.

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## 11 Plagiarism

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Plagiarism is defined as submitting as one's own work that which derives in part or in its entirety from the work of others without due acknowledgement. It is both poor scholarship and a breach of academic integrity. The University views plagiarism as a serious matter and, under Discipline Regulation 6, has the power to take disciplinary action against those found guilty of plagiarising the work of others.

The general university statement on plagiarism, and further general advice on plagiarism and how to avoid it, is given on the University's plagiarism and good academic practice website [www.cam.ac.uk/plagiarism](http://www.cam.ac.uk/plagiarism). Generally the Department follows the advice and policies set out by the University. This section gives further guidance as to how these policies apply to study in the Department of Chemistry.

### *Supervision work and Tripos questions*

The majority of questions set as supervision work and in Tripos examinations take the form of problems to be solved. In presenting their solutions to these problems students are not expected to quote the source or authority of the facts, theories and concepts they use to formulate their solutions.

### *Continuously assessed work (principally practical work)*

Here the rules against plagiarism are especially relevant as they prohibit copying and colluding. Basing a write-up on data or answers provided by another student is an example of plagiarism (or, more simply, cheating). The following rules apply to all continuously assessed work

- Unless otherwise instructed, you must work alone. Where you are permitted to work in a group, the names of those you have worked with must be stated on your practical write-up.
- The write-up must be entirely your own work. In particular, you may not use spreadsheets or templates prepared by others.
- It is expressly forbidden to invent, falsify or modify data, spectra or observations, or to use data, spectra or samples obtained from other persons unless authorised to do so by a Senior Demonstrator.
- Where data from other sources is quoted in a write-up, the source must be identified.

### *Part III project*

Students must be particularly mindful of the need to avoid plagiarism when preparing their project report. This means being sure to acknowledge the source of ideas, data and diagrams by a reference given in the accepted form (i.e. to a published book or paper). Where the work has been collaborative, it is important to make clear the extent of the collaboration, and which parts of the work presented in the report are the results of collaboration. The following are all examples of plagiarism in project reports

- Quoting directly another person's language, data or illustrations without clear indication that the authorship is not your own and without giving due acknowledgement of the source.
- Paraphrasing the critical work of others without due acknowledgement – even if you change some words or the order of the words, this is still plagiarism if you are using someone else's original ideas and are not properly acknowledging it.
- Using ideas taken from someone else without reference to the originator.
- Cutting and pasting from the Internet to make a 'pastiche' of online sources.
- Submitting as part of your own project, report or dissertation, someone else's work without identifying clearly who did the work (for example, where research has been contributed by others to a joint project).

Plagiarism can occur in respect to all types of sources and all media:

- not just text, but also illustrations, computer code, experimental results etc;
- not just text published in books and journals, but also downloaded from websites or drawn from other media;
- not just published material but also unpublished works, including lecture handouts and the work of other students.

The following summarizes succinctly the key point:

*The Golden Rule: The examiners must be in no doubt as to which parts of your work are your own original work, and which are the rightful property of someone else.*

## 12 Examinations

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Which papers you sit, and the structure of the papers, depends on whether or not you are taking any interdisciplinary courses.

### *Arrangements for candidates not taking any interdisciplinary courses*

There are three papers set, each of three hours duration.

**Paper 1A** will contain one question relating to each Part III lecture course; candidates will be required to answer *six* questions. The short questions on this paper will be designed to test the basic understanding of the subject material.

**Paper 2** will be divided into as many sections as there are courses given in the Michaelmas Term; each section will contain two questions. Candidates will be required to answer *four* questions, taken from at least *three* different sections. The longer questions on this paper will be designed to test a deeper understanding of the subject material.

**Paper 3A** will be divided into as many sections as there are courses given in the Lent Term; each section will contain two questions. Candidates will be required to answer *four* questions, taken from at least *three* different sections. The longer questions on this paper will be designed to test a deeper understanding of the subject material.

Each paper is preceded by an extra ten minutes during which you may read the paper, but not write your answers.

### *Arrangements for candidates taking interdisciplinary courses*

If you are taking one or more of the interdisciplinary courses I1, I2 and I3, then special arrangements apply.

1. You are permitted to offer up to *two* interdisciplinary courses.
2. For each interdisciplinary course offered you will sit a 90 minute written paper (the Interdisciplinary Papers, details below) devoted to that course.
3. All candidates must take Paper 2.
4. If you are offering **one** interdisciplinary course then you must also take
  - (a) Paper 1B which has the same structure as Paper 1A, but from which you have to answer *five* questions in a time of 2 hours 30 minutes.
  - (b) Paper 3B which has the same structure as Paper 3A, but from which you have to answer *three* questions, taken from at least *two* different sections, in a time of 2 hours 15 minutes.
5. If you are offering **two** interdisciplinary courses then you must also take
  - (a) Paper 1C which has the same structure as Paper 1A, but from which you have to answer *four* questions in a time of 2 hours.
  - (b) Paper 3C which has the same structure as Paper 3A, but from which you have to answer *two* questions, without restriction, in a time of 1 hours 30 minutes.

## *Interdisciplinary papers*

Each interdisciplinary course is examined in a separate paper which lasts for 90 minutes. For course I1 the paper will contain three questions, of which candidates are required to answer two. When you complete your exam entry form (online via *CamSIS*) you will have to indicate whether or not you wish to take I1, I2 or I3. We appreciate that you are being asked this question before the lectures have been given, so that you cannot answer it sensibly. We recommend that in the first instance you *do not* indicate that you want to take I1, I2 or I3. In the middle of the Lent Term, when you are ready to make a decision, you can change your examination entry to include these interdisciplinary courses, if you so wish. *Please note that only your College Tutorial Office can make such a change on your behalf; the Teaching Office cannot do this.*

## *Data book and molecular models*

In all of the examinations you will be provided with a Data Book (identical to the one you used in Part IB and Part II) which contains a simple Periodic Table, values of physical constants, certain mathematical formulae and definitions and selected character tables. A copy of the Data Book is available at [www.ch.cam.ac.uk/teaching/data-book](http://www.ch.cam.ac.uk/teaching/data-book). You may take (unassembled) molecular models into the examinations.

## *Timetable for the examinations and orals*

Although the Examination timetable will not be announced formally until early in the Easter Term, we expect the papers to be scheduled as follows (all 2022): Paper 2 Monday 30th May, Paper 3 Wednesday 1st June, and Paper 1 Friday 3rd June all 0900–1200 (note the order of the papers). You are given an extra ten minutes to read each of the papers, on account of their complexity. The examination for IDP1 will be held at 1330 on Thursday 2nd June.

We also expect that oral examinations, if required, will be held in the late morning of Tuesday 21st June 2022, and that the class list will be posted on Wednesday 22nd June. Please note that these dates are all provisional and subject to confirmation. You must be in Cambridge and available for an oral examination on the day announced.

## *Pass marks and carrying forward marks*

The regulations allow the Part III examiners to take into account a candidate's performance in Part II from the previous year. In effect, this means that marks will be 'carried forward' from Part II to Part III.

Our expectation is that the Part III examiners will, in the first instance, draw up the class list by combining the Part II and Part III marks with the following weighting:

Part II	15%
Part III Project	35%
Part III Written Papers	50% (i.e. 16.7% for each).

The Examiners may, however, at their discretion alter the weight given to different papers or the dissertation. The final allocation of a class will not simply be done by a mechanical process. Rather, the Examiners will consider each candidate's mark profile and will give particularly careful consideration to candidates who fall on class boundaries or for whom there is a large discrepancy between their Part II and Part III marks, or between the marks on the written papers and on the project.

**Please note that to be awarded a pass in the whole examination candidates will need to achieve: (1) a pass mark (40%) in the combined total of the Part III written papers, AND (2) a pass mark (40%) for the dissertation.**

## *Disclosure of examination marks*

The marks which are disclosed (via *CamSIS*) are those for each of the papers, a mark for the dissertation, and the final overall total and class. In addition you will be notified separately of your question-by-question marks, and a break down of your marks for the dissertation in the categories listed above.

## *Senior Examiner*

The Senior Examiner for Part III Chemistry in 2021/2022 is Dr Finian Leeper.

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## **13**

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### **Chemistry teaching website**

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You can find up-to-date information on the course and other related matters from the teaching web site: [www.ch.cam.ac.uk/teaching](http://www.ch.cam.ac.uk/teaching).

Lecture handouts and other course materials will be posted in *Moodle*: [www.vle.cam.ac.uk](http://www.vle.cam.ac.uk). If you find that you do not have access to the Chemistry part of Moodle, please email the Teaching Office on [teaching.office@ch.cam.ac.uk](mailto:teaching.office@ch.cam.ac.uk).

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## **14**

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### **Chemistry Consultative Committee**

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The Chemistry Consultative Committee consists of representatives of students and academic staff. It meets towards the end of each term and is a forum for the discussion of all aspects of the teaching of Chemistry in the Department. Student representatives are elected during the Michaelmas term; comments and suggestions can be passed on to them so that they can be discussed at the meetings.

The minutes of previous meetings and the composition of the committee can be found on the teaching website:

[www.ch.cam.ac.uk/teaching/student-consultative-committee](http://www.ch.cam.ac.uk/teaching/student-consultative-committee)

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## **15**

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### **The Department of Chemistry Library**

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The Chemistry Department Library will unfortunately NOT be open to undergraduates during COVID-19 pandemic.

All the information that you will need about how to access online resources remotely, and much more, will be available from the Chemistry Library website at:

[www-library.ch.cam.ac.uk](http://www-library.ch.cam.ac.uk)

### ***Reading Lists Online (RLO)***

The link below gives access to the online reading lists for all the Chemistry courses. They have been compiled to follow the structure of the Course Guides. Each one includes a record of the borrowable items held in the Cambridge University Libraries' collections (including the Chemistry Library) and those accessible as eBook titles.

[www-library.ch.cam.ac.uk/reading-lists](http://www-library.ch.cam.ac.uk/reading-lists)

In order to access areas of the Department other than the lecture theatres you will need your University card so that you can pass the turnstiles and various internal doors. You should therefore make it a point to *always* bring your card with you when you come to the Department.

We hope that by the time you arrive you will already have the appropriate access. If you find that your access rights are different to others in your year group, or access suddenly stops, please contact Mifare Admin ([mifareadmin@ch.cam.ac.uk](mailto:mifareadmin@ch.cam.ac.uk)). In general you will *not* have access to research areas other than that needed for your project work; you will need your group leader to request access to appropriate areas.

Your card will give you access to the building from 08:00–20:00 Monday - Saturday. Outside these times you are not permitted to be in the Department unless some specific arrangement has been made. If you remain in the Department after 20:00 you risk becoming trapped by the security doors and/or the turnstiles.

### *Cybercafé*

The Departmental tea room (Cybercafé) is located on the top floor of the Centre for Molecular Informatics Building. Service is available from 09:30 – 15:45. Hot and cold drinks, as well as a selection of snack foods are available. Part III students working in the labs on experimental projects are welcome in the Cybercafé but please bear in mind there is limited space and it is intended for use by the research workers and staff in the Department.

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**Part III Chemistry 2021/2022: Titles of lecture courses**


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<b>Title</b>	<b>Lecturer(s)</b>	
<b>Michaelmas Term</b>		
M0	Advanced polymer chemistry	Scherman(9), Bronstein (3)
M1	Inorganic materials	Wood
M2	Bio-inorganic chemistry	Barker
M3	Soft matter-from molecules to materials	Knowles (6),Michaels (6)
M4	Energy landscapes and soft matter	Jack (6), Wales (6)
M5	Stereocontrolled organic synthesis	Fawcett (3), Trowbridge (3), Goodman (6)
M6	Computer simulation methods in chemistry and physics	Espinosa (3), Joseph (3), Collepardo(6)
M8	Main group organometallics	Wheatley (6), Less (6)
M9	Aromatic Heterocycles and Medicinal chemistry	Smith
<b>Lent Term</b>		
L1	Catalysis in synthesis	Phipps
L3	Electronic structure of solid surfaces	Jenkins
L4	Chemical biology and drug discovery	Bernardes (6), Coyne (6)
L5	Solid electrolytes	Elliott (6), Taraskin (6)
L6	Supramolecular chemistry and self-organisation	Nitschke
L7	Chemical dynamics and machine learning	Colwell (3), Wales (3), Althorpe (6)
L8	Total synthesis	Gaunt
L9	Biosynthesis	Leeper
<b>Lent Term – Interdisciplinary Courses</b>		
I1	Atmospheric chemistry and global change hosted by the Department of Chemistry	Prof. John Pyle and others
I2	The Earth System and Climate change hosted by the Department of Earth Sciences	Dr Luke Skinner and Prof. Eric Wolff
I3	Materials, electronics and renewable energy hosted by the Department of Physics	Dr Siân Dutton, and Dr Akshay Rao



### Part III Chemistry – Michaelmas Term 2021

Wk	Date	Day	09:00	10:00	11:00	12:00	Courses
1	7/10	Th	M1	M4	M0		M0 M1  M4 M5
	8/10	Fr	M4	M5			
	11/10	Mo	M1	M5	M0		
	12/10	Tu	M4		M0		
	13/10	We	M1	M5			
2	14/10	Th	M1	M4		M0	
	15/10	Fr	M4	M5			
	18/10	Mo	M1	M5	M0		
	19/10	Tu	M4		M0		
	20/10	We	M1	M5			
3	21/10	Th	M1	M4	M0		
	22/10	Fr	M4	M5			
	25/10	Mo	M1	M5	M0		
	26/10	Tu	M4		M0		
	27/10	We	M1	M5			
4	28/10	Th	M1	M4	M0		
	29/10	Fr	M4	M5			
	1/11	Mo	M1	M5	M0		
	2/11	Tu	M4		M0		
	3/11	We	M1	M5			
5	4/11	Th	M6	M8			M2 M3 M6 M8 M9
	5/11	Fr	M8	M2	M9	M3	
	8/11	Mo	M6	M2	M9	M3	
	9/11	Tu	M8				
	10/11	We	M6	M2	M9	M3	
6	11/11	Th	M6	M8			
	12/11	Fr	M8	M2	M9	M3	
	15/11	Mo	M6	M2	M9	M3	
	16/11	Tu	M8				
	17/11	We	M6	M2	M9	M3	
7	18/11	Th		M8	M9		
	19/11	Fr	M8	M2	M6	M3	
	22/11	Mo	M6	M2	M9	M3	
	23/11	Tu	M8		M9		
	24/11	We	M6	M2		M3	
8	25/11	Th	M6	M8	M9		
	26/11	Fr	M8	M2		M3	
	29/11	Mo	M6	M2	M9	M3	
	30/11	Tu	M8		M9		
	1/12	We	M6	M2	M9	M3	

Please note that the lectures are not always in a regular pattern – check times and dates carefully

### Part III Chemistry – Lent Term 2022

Wk	Date	Day	09:00	10:00	11:00	12:00	Courses
1	20/1	Th	I1	I2	L4	I3	L1 L3 L4
	21/1	Fr	L1		L3	L4	
	24/1	Mo	L1		L3	L4	
	25/1	Tu	I1	I2		I3	
	26/1	We	L1		L3		
2	27/1	Th	I1	I2	L4	I3	
	28/1	Fr	L1		L3	L4	
	31/1	Mo	L1		L3	L4	
	1/2	Tu	I1	I2		I3	
	2/2	We	L1		L3		
3	3/2	Th	I1	I2	L4	I3	
	4/2	Fr	L1		L3	L4	
	7/2	Mo	L1		L3	L4	
	8/2	Tu	I1	I2		I3	
	9/2	We	L1		L3		
4	10/2	Th	I1	I2	L4	I3	
	11/2	Fr	L1		L3	L4	
	14/2	Mo	L1		L3	L4	
	15/2	Tu	I1	I2		I3	
	16/2	We	L1		L3		
5	17/2	Th	I1	I2	L8	I3	L5 L6 L7 L8 L9
	18/2	Fr	L5	L6	L9	L7	
	21/2	Mo	L5	L6	L7	L9	
	22/2	Tu	I1	I2	L8	I3	
	23/2	We	L5	L6	L8	L9/L7	
6	24/2	Th	I1	I2	L8	I3	
	25/2	Fr	L5	L6	L9	L7	
	28/2	Mo	L5	L6	L7	L9	
	1/3	Tu	I1	I2	L8	I3	
	2/3	We	L5	L6	L8	L9/L7	
7	3/3	Th	I1	I2	L8		
	4/3	Fr	L5	L6	L9	L7	
	7/3	Mo	L5	L6	L7	L9	
	8/3	Tu	I1	I2	L8	L7	
	9/3	We	L5	L6	L8	L9	
8	10/3	Th	I1	I2	L8		
	11/3	Fr	L5	L6	L9	L7	
	14/3	Mo	L5	L6	L7	L9	
	15/3	Tu	I1	I2	L8	L7	
	16/3	We	L5	L6	L8	L9	

Please note that the lectures are not always in a regular pattern – check times and dates carefully