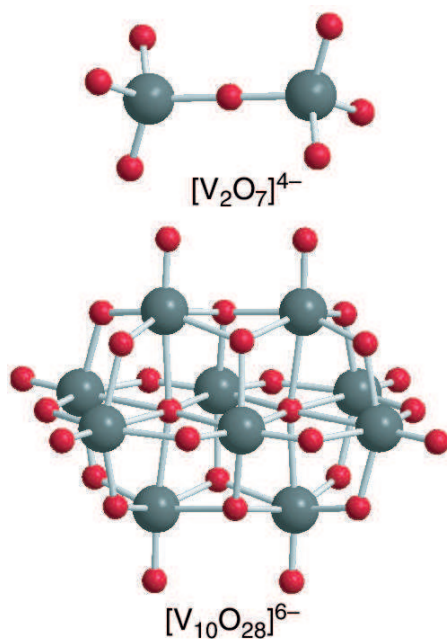




UNIVERSITY OF
CAMBRIDGE

Department of Chemistry

IB Chemistry:
A Guide to the Course



Academic Year 2017/2018

IB Chemistry 2017/18

Chemistry A lectures are at 12:00 in the Wolfson Lecture Theatre

*Chemistry B lectures are at 09:00 in the Wolfson Lecture Theatre; the lectures will start **promptly** at 09:00*

Michaelmas				
		A	B	
1	5/10	Th	JHK	WPN
	6/10	Fr		
	7/10	Sa	SCA	WPN
	9/10	Mo		
	10/10	Tu	SCA	WPN
	11/10	We		
2	12/10	Th	SCA	WPN
	13/10	Fr		
	14/10	Sa	SCA	WPN
	16/10	Mo		
	17/10	Tu	SCA	WPN
	18/10	We		
3	19/10	Th	SCA	AGC
	20/10	Fr		
	21/10	Sa	RLJ	AGC
	23/10	Mo		
	24/10	Tu	RLJ	AGC
	25/10	We		
4	26/10	Th	RLJ	AGC
	27/10	Fr		
	28/10	Sa	RLJ	AGC
	30/10	Mo		
	31/10	Tu	RLJ	PDW
	1/11	We		
5	2/11	Th	RLJ	PDW
	3/11	Fr		
	4/11	Sa	SCA	PDW
	6/11	Mo		
	7/11	Tu	SCA	PDW
	8/11	We		
6	9/11	Th	SCA	PDW
	10/11	Fr		
	11/11	Sa	SCA	PDW
	13/11	Mo		
	14/11	Tu	SCA	PDW
	15/11	We		
7	16/11	Th	SCA	JMG
	17/11	Fr		
	18/11	Sa	SCA	JMG
	20/11	Mo		
	21/11	Tu	RLJ	JMG
	22/11	We		
8	23/11	Th	JHK	JMG
	24/11	Fr		
	25/11	Sa	JHK	JMG
	27/11	Mo		
	28/11	Tu	JHK	JMG
	29/11	We		

Lent				
		A	B	
1	18/1	Th	JHK	SDP
	19/1	Fr		
	20/1	Sa	JHK	SDP
	22/1	Mo		
	23/1	Tu	JHK	SDP
	24/1	We		
2	25/1	Th	JHK	SDP
	26/1	Fr		
	27/1	Sa	JHK	SDP
	29/1	Mo		
	30/1	Tu	JHK	SDP
	31/1	We		
3	1/2	Th	JHK	SDP
	2/2	Fr		
	3/2	Sa	JHK	SDP
	5/2	Mo		
	6/2	Tu	JHK	SDP
	7/2	We		
4	8/2	Th	JHK	PDB
	9/2	Fr		
	10/2	Sa	JHK	PDB
	12/2	Mo		
	13/2	Tu	LJC	PDB
	14/2	We		
5	15/2	Th	LJC	PDB
	16/2	Fr		
	17/2	Sa	LJC	PDB
	19/2	Mo		
	20/2	Tu	LJC	PDB
	21/2	We		
6	22/2	Th	LJC	PDB
	23/2	Fr		
	24/2	Sa	LJC	PDB/SDP
	26/2	Mo		
	27/2	Tu	LJC	AEHW
	28/2	We		
7	1/3	Th	LJC	AEHW
	2/3	Fr		
	3/3	Sa	LJC	AEHW
	5/3	Mo		
	6/3	Tu	LJC	AEHW
	7/3	We		
8	8/3	Th	LJC	AEHW
	9/3	Fr		
	10/3	Sa	LJC	AEHW
	12/3	Mo		
	13/3	Tu	LJC	AEHW
	14/3	We		

Easter				
		A	B	
0	25/4	We	JHK†	CAH†
1	26/4	Th	JHK	CAH
	27/4	Fr		
	28/4	Sa	JHK	CAH
	30/4	Mo		
	1/5	Tu	JHK	CAH
	2/5	We		
2	3/5	Th	JHK	CAH
	4/5	Fr		
	5/5	Sa	JHK	CAH
	7/5	Mo		
	8/5	Tu	JHK	CAH
	9/5	We		
3	10/5	Th	JHK	CAH
	11/5	Fr		
	12/5	Sa	JHK	CAH
	14/5	Mo		
	15/5	Tu	JHK	CAH
	16/5	We		
4	17/5	Th	JHK	CAH
	18/5	Fr		
	19/5	Sa		
	21/5	Mo		SRB‡
	22/5	Tu		
	23/5	We		SRB‡

†Note that the first lecture in the Easter Term is given on Wednesday

‡Inorganic chemistry revision lectures; both at 12:00

Contents

	inside front cover
Lecture timetable	
1 Introduction	1
2 Outline of the courses	2
3 Lecture synopses for Course A	3
4 Recommended books for Chemistry A	5
5 Lecture synopses for Course B	6
6 Recommended books for Chemistry B	10
7 Practical work	11
8 Plagiarism	13
9 Examinations	14
10 Disclosure of examination marks	17
11 Chemistry teaching website	17
12 Chemistry Consultative Committee	17
13 Further details of the department	17
14 Library, photocopying and computing	19
15 Looking ahead: Chemistry in the third year and beyond	20

1 Introduction

The second-year courses build on the topics studied in the first year and explore these chemical ideas and principles in more depth. A broad range of topics is covered and the connections between these different topics are emphasised, as is the way in which one idea grows from another and can be developed to aid our understanding of chemistry as a whole. The courses lay a firm foundation of chemical principles which inform both more advanced study of chemistry and also related areas such as Biochemistry, Physics, Molecular Biology, Materials Science and Earth Sciences.

Two courses are offered in the second year: Chemistry A and Chemistry B; students may take either or both of them. Chemistry A focusses mainly on the theories which are used to understand and probe chemical bonding, structures and reactions. It starts out with a discussion of quantum mechanics which is the fundamental theory used by chemists to understand the microscopic nature of matter and molecules. The course goes on to use these ideas to discuss chemical bonding, the way in which microscopic properties influence those of bulk matter, and how all of these ideas can be used together to understand the properties and chemistry of solid materials. The underlying theme which runs through the course is endeavouring to understand the microscopic nature of molecules, matter and reactions.

Chemistry B focusses mainly on how chemists find out about and rationalise the enormous range of chemical structures and reactions that are known; a wide range is covered, from the familiar world of carbon-based chemistry, through the huge diversity of compounds and structures that are the domain of inorganic chemistry, and finally to the important topic of biological chemistry, in which we look at the chemistry of life. Despite the huge range that the course will cover, we will find that we can begin to make sense of it all by using a relatively small number of key concepts in chemical bonding and reactivity. As the discussion develops, the central role taken by electronic structure and the three-dimensional shape of molecules becomes apparent; it is these properties that influence their reactivity and other properties.

If you are planning on continuing with chemistry in the third, and possibly fourth, year, the best choice is to take both Chemistry A and B in the second year. By doing this, you will have the best coverage of chemistry, and be able to choose from the full range of specialist courses on offer in the final years. A route is provided within Part II Chemistry for those who have only taken Chemistry B in Part IB, but it is important to realise that by taking this route you will have a more restricted range of options. If you have only taken Chemistry A it may be possible to continue with Part II, but you will need to undertake some directed study over the preceding vacation.

Within IB Natural Sciences there are many courses which complement the two chemistry courses. Physics, Materials Science, and Mathematics are commonly taken alongside Chemistry A. Any of the biological courses with a more 'molecular' slant sit well with Chemistry B, and those with interests in Earth Sciences will find useful content in both Chemistry A and B.

The individual lecture courses in Chemistry A and Chemistry B are outlined below, and a complete timetable is given on the inside of the cover page.

2 **Outline of the courses**

Chemistry A and Chemistry B are outlined below: follow the tables vertically down the page. The number of lectures in each course is given in the bracket. A complete timetable is given on the reverse of the front cover.

Chemistry A	Chemistry B
<i>Michaelmas Term</i>	<i>Michaelmas Term</i>
Introduction to quantum mechanics* (13)	Aromatic and enolate chemistry (6)
Molecular spectroscopy* (7)	Conjugate addition and chirality (5)
Symmetry and bonding I (3)	Introduction to stereochemistry (7)
	Shape and organic reactivity (6)
<i>Lent Term</i>	<i>Lent Term</i>
Symmetry and bonding II (11)	Coordination chemistry (9)
Molecular energy levels and thermodynamics (13)	Organometallic chemistry (8)
	Structure, bonding and the p-block elements (7)
<i>Easter Term</i>	<i>Easter Term</i>
Electronic structure and properties of solids (12)	Introduction to chemical biology (11)

*These courses are interspersed with one another

Introduction to quantum mechanics: 13 lectures

Prof. Stuart Althorpe

The principles of Quantum Mechanics underlie all of chemistry at the molecular level, and provide a foundation on which the subsequent courses in Chemistry A are built. This course will introduce the fundamental ideas of quantum mechanics, and show how they may be applied to some simple but important examples: the harmonic oscillator, the rigid rotor and the hydrogen atom.

From there we shall move on to many-electron atoms and the consequences of electron spin, and finally show how the variation principle leads to an understanding of chemical bonding.

Mathematically, all that is required is some fluency with Part IA Mathematics (course A). The practical course in the Michaelmas Term contains a set of computer-based exercises designed to illustrate the contents of this course.

Molecular spectroscopy: 7 lectures

Prof. Rod Jones

Spectroscopy provides us with some of the best evidence for the quantization of energy. This course is integrated with the Quantum Mechanics course and illustrates how the key ideas may be used to understand the appearance of spectra and allow us to determine fundamental molecular parameters. The course also provides the background for the laboratory sessions where you will be able to put the theory into practice.

We shall start with the rotational spectra of diatomic molecules and its applications from microwave spectroscopy in the labs, which allows us to determine bond lengths in simple molecules, to radio astronomy which allows us to determine the composition of heavenly bodies. We shall then examine vibrational spectroscopy using both the harmonic oscillator and Morse oscillator as models. Finally, we shall touch on the electronic spectroscopy of atoms and simple molecules.

Symmetry and bonding: 14 lectures

Dr James Keeler

Humans seem to have an innate ability to recognise and appreciate the symmetry of objects, and chemists seem to be especially fascinated by molecules or other structures which display high or unusual symmetry. In this course we will show how *Group Theory* provides a formal framework for describing the symmetry of molecules and how this theory can be used as a powerful tool for predicting the properties and behaviour of molecules. In particular we will look at how symmetry helps us to construct molecular orbital (MO) diagrams and then how these can be used to understand key properties such as shape or stability.

We will also see how symmetry helps us to understand the vibrations of molecules via a normal mode analysis. Finally, we will look at how we can actually calculate the energies and form of the MOs in simple molecules using the Hückel approach. The application of symmetry to such calculations results in considerable simplification.

This course will take a relatively informal approach to Group Theory with the emphasis being on developing a practical set of tools which can be applied with ease.

Introducing Group Theory Symmetry elements and symmetry operations. Point groups. Character tables. Representations. Direct products.

Applications Vanishing integrals. Symmetry orbitals and molecular orbitals. Transition metal complexes. Hückel MO calculations. Normal mode analysis and vibrational spectroscopy. Dipole moments and chirality. Infinite groups and the symmetry of electronic states.

Molecular energy levels and thermodynamics: 13 lectures

Dr Lucy Colwell

Quantum mechanics provides us with a detailed description of the energy levels of single atoms and molecules, but when we are doing chemistry we deal not with one molecule at a time but vast numbers. The question is, then, how are the properties of bulk matter related to the energy levels of the molecules of which it is composed? The methods of *statistical thermodynamics*, which are introduced in this course, make this connection. In particular, we will see how the thermodynamic properties of matter (internal energy, entropy, Gibbs energy etc.) can be calculated from a knowledge of the molecular energy levels. As you will have seen in the earlier courses, these energy levels can be predicted by quantum mechanics and determined experimentally from spectroscopy. We will also investigate the Boltzmann distribution which is used to understand many molecular phenomena.

The course closes with a number of applications of the ideas developed in the earlier part. We will look at how it is possible to understand the temperature variation of heat capacities, and how it is possible to predict the values of equilibrium constants simply from spectroscopic data. Statistical thermodynamics can also be used to predict the values of reaction rate constants using transition state theory. We will look at how this is developed and the interpretation of the parameters involved.

Topics Review of thermodynamic ideas: the Second Law, internal energy, the Gibbs and Helmholtz functions. Microstates and macrostates: the canonical distribution function, the partition function and thermodynamics quantities.

Evaluation of the partition function: translation, rotation and vibration.

Internal energy and heat capacities; temperature variation. Calculation of absolute entropies.

Chemical equilibrium and the prediction of equilibrium constants.

Transition state theory: concept of a potential energy surface and the transition state; formulation in terms of partition functions; comparison with collision theory. Thermodynamic formulation.

The Boltzmann distribution; applications in spectroscopy. Density of states.

Electronic structure and properties of solids: 12 lectures

Dr James Keeler

The objective of this course is to introduce the concepts of structure and bonding that are required to explain the behaviour of electrons in solids. The course is designed in such a way that it builds upon the material presented in all of the preceding courses in Chemistry A. At the heart of the course lie two contrasting models for the behaviour of electrons in solids – the free electron and the LCAO models.

Free electron theory is used as a starting point because it is simple and it permits the introduction of essential concepts such as wavevectors, travelling waves and the Fermi surface. However, this theory does not take account of the presence of atoms and orbitals and offers no structural predictions. LCAO theory is used to show how atomic orbitals may be used as a basis for constructing wavefunctions appropriate for solids. This theory is used to explain the bonding and energy bands in a wide variety of solids.

The last part of the course focuses on semi-conductors and doped semi-conductors which are exceptionally important as they are used to create the basic building blocks of all modern electronic devices.

Topics Introduction to the description of crystalline materials: lattices; unit cells; space filling.

The free-electron theory of solids: plane waves; the reciprocal lattice; wavevectors.

The Fermi–Dirac distribution: the Fermi level; the Fermi energy; the Fermi surface.

Electrical conductivity and other physical properties.

Tight-binding model for solids: bands; band gaps; band structure.

Semiconductors: doping; electrical properties; spectroscopic properties.

Electronic devices: the p-n junction; transistors.

4 Recommended books for Chemistry A

These recommended books should be in your College Library. They can also be consulted in the Departmental Library, and some are available on short loans. The designations in brackets [. . .] are the class marks used to identify the books in the Chemistry Department Library, and you should find these texts shelved separately as the *Blue Book* collection in Unit 17, on the right hand side as you enter the library.

Quantum mechanics

Green N.J.B. *Quantum Mechanics 1: Foundations*, Oxford Chemistry Primers, 1997. [QC174.12.G74]

For reference: McQuarrie, D.A, and Simon, J.D, *Physical Chemistry: A Molecular Approach*, University Science Books, 1997. [QD453.M37]

For reference: Atkins P.W. & Friedman R.S. *Molecular Quantum Mechanics*, any edition, OUP. [QD462.A85]

Steiner E. *The Chemistry Maths Book*, OUP, 1996. [QA37.3.S74]

Molecular spectroscopy

Banwell, C. and McCash, E., *Fundamentals of Molecular Spectroscopy*, 4th edition, McGraw Hill [QD96.M65.B36]

For reference: McQuarrie, D.A, and Simon, J.D, *Physical Chemistry: A Molecular Approach*, University Science Books, 1997. [QD96.M65.B36]

Symmetry and bonding

Vincent A. *Molecular Symmetry and Group Theory*, 2nd edition, Wiley, 2001. [QD461.V56]

For reference: Cotton F.A. *Chemical Applications of Group Theory*, Wiley, 3rd Edn, 1990. [QD461.C68]

For reference: McQuarrie, D.A, and Simon, J.D, *Physical Chemistry: A Molecular Approach*, University Science Books, 1997. [QD453.M37]

Molecular energy levels and thermodynamics

Maczek A.O.S *Statistical Thermodynamics* (Oxford Chemistry Primers 58), OUP 1998. [QD504.M33]

Gasser R.P.H. and Richards W. G. *An Introduction to Statistical Thermodynamics*, World Scientific, 1995. [QC311.5.G37]

Electronic structure and properties of solids

Smart, L. and Moore, E., *Solid State Chemistry*, 2nd Edn, Chapman and Hall, 1996 [QD478.S63]
West, A.R., *Basic Solid State Chemistry*, Wiley 1988 [QD478.W47]
Cox P.A. *The Electronic Structure and Chemistry of Solids*, Oxford Science Publication, 1992.
[QD478.C69]
For reference: Singleton J., *Band Theory and Electronic Properties of Solids*, OUP 2001.
[QC176.8.E4.S56]
For reference: Elliott S. R. *Physics and Chemistry of Solids*, Wiley 1998. [QC176.5.E45]

5

Lecture synopses for Course B

Aromatic and enolate chemistry: 6 lectures

Dr Bill Nolan

This course is divided into two sections. The first looks at the structure and reactivity of the benzene ring and explores the attack of electrophiles as the key reaction. In the second part we look at the formation and reactions of enols and enolates – these are nucleophilic species that allow the synthetic chemist to construct a wide range of new bonds adjacent to the carbonyl group.

Topics Electrophilic aromatic substitution

- Aromaticity and aromatic Compounds
- Electrophilic aromatic substitution
- Reactions on substituted benzene derivatives
- Substituent effects and multi-step reactions

Enols and enolates

- Carbonyl-enol tautomerism
- Acid and base catalysed enolisation
- Electrophilic addition to enols and enolates
- Stable enolate synthetic equivalents
- Alkylation issues and solutions
- Alternative enolate functionalities

Nucleophilic attack on π systems: 5 lectures

Dr Anthony Coyne

The conjugation of alkenes with electron-withdrawing groups makes them electrophilic and susceptible to attack by nucleophiles. Conjugate addition, an important type of reaction involving nucleophilic addition to the remote end of an alkene conjugated with an electron-withdrawing group, is discussed in detail. If the electron-withdrawing group in question is a carbonyl, the nucleophile can react either at the alkene (conjugate addition) or at the carbonyl (direct addition). Factors influencing the selectivity between these two modes of addition (the regioselectivity of nucleophilic addition) are examined. Both direct addition and conjugate addition can create chiral carbon centres (carbon centres with four different substituents attached).

A basic introduction to chirality is given, with a focus upon compounds containing one chiral carbon centre. The Cahn–Ingold–Prelog system for labelling the configuration of chiral carbon centres and alkene geometries is described.

Nucleophilic substitution at conjugated alkenes bearing a leaving group (conjugate substitution) is discussed. A related type of reaction involving nucleophilic substitution on aromatic rings (nucleophilic aromatic substitution) is examined.

Topics Conjugate addition with α , β -unsaturated carbonyls.

Direct addition versus conjugate addition.

Conjugate addition with other electron-deficient alkenes.

Introduction to chirality.

Labelling chiral centres: the Cahn–Ingold–Prelog rules.

Conjugate substitution.

Nucleophilic aromatic substitution.

Introduction to stereochemistry: 7 lectures

Dr Peter Wothers

Molecular shape and reactivity is the foundation of organic chemistry. We need to be able to understand the critical, and often subtle, interactions between the shape of a molecule and its reactions. In three dimensions, molecules have more flexible shapes than two-dimensional structures with rigid π systems. In this course we will look at the different conformations that molecules can adopt and how stereochemistry plays an important role in determining reactivity.

Topics Introduction to Chirality.

Stereochemistry with two or more chiral centres.

Resolution of enantiomers by forming diastereoisomers.

Elimination reactions.

Conformational analysis of chains and rings.

Cyclisation reactions.

Shape and organic reactivity: 6 lectures

Prof. Jonathan Goodman

The final part of the course will combine the concepts of two- and three-dimensional shape, stereochemistry and NMR and apply these to the analysis a variety of reactions. These ideas can then be applied to some unfamiliar systems to work out how they might react.

Topics Alkynes and alkenes.

Bases and nucleophiles.

Kinetic and thermodynamic control.

Imines, oximes, and hydrazones.

Beckmann rearrangement.

Acetals and aldols.

Stereoselective reactions on chiral molecules.

Coordination chemistry: 9 lectures

Dr Sebastian Pike

The coordination chemistry of first row transition metals will be explored, focusing on the role of d-orbitals and d-electrons in their chemistry. The course will discuss the synthesis and reactivity of basic coordination complexes and explore the possibilities for isomerism. Both Crystal Field Theory and qualitative molecular orbital diagrams will be used to explain the splitting of the d

orbitals in appropriate geometries and the effects of both ligand and metal on the extent and nature of the splitting will be included. An introduction to the consequences of the d-orbital splitting on complex properties will be given, focusing on trends in ionisation energy, preferred geometries, oxidation states, high spin and low spin complexes and the magnetic properties of transition metal ions.

Topics Properties of the transition metals

Coordination compounds - coordination numbers, stereochemistry, synthesis, reactivity

Crystal Field Theory

Spectrochemical Series

Molecular Orbital Theory

Organometallic chemistry: 8 lectures

Dr Paul Barker

The interaction of transition metal ions with organic compounds transforms the properties of both components. This interplay is at the centre of organometallic chemistry, which generally refers to compounds containing metal–carbon bonds. This course will pick up from the metal–carbonyl compounds already introduced and develop further the molecular orbital approach to understanding the bonding in metal complexes with π -bonded organic compounds. The study of organometallics is relatively young yet has contributed greatly to inorganic chemistry and its relevance goes far beyond simple structures, having important applications in catalytic, synthetic and polymer chemistries.

The aim of this course is therefore to provide an introduction to the chemistry of these fascinating compounds, the structures they adopt and the various treatments of their bonding modes. Some syntheses will be described and the methods of characterisation outlined.

Specific topics covered with include: π -acceptors and the Dewar–Chatt model, the spectroscopic study of metal carbonyls, electron–counting, the $18e^-$ rule and exceptions to it, sandwich complexes, hapticity, fluxionality and metal–metal bonds. We will consider changes in oxidation state and coordination number as organic molecules react with transition metals and then bring these fundamental ideas together to show how transition metals complexes can act as potent catalysts in a variety of important reactions. Several key transformations commonly used in research labs and in industrial processes will be used to illustrate the huge importance of these catalysts.

Coordination and organometallic chemistry: summary lecture

The Coordination and Organometallic chemistry courses cover the fundamental principles that govern the behaviour of the first row transition metal ions and their ligands. At the end of the two courses, Dr Pike and Dr Barker will demonstrate how the topics that have been discussed are relevant to current research by drawing on examples from the recent literature. In addition, in the summary lecture, the lecturers will use examples of recent Tripos questions to demonstrate how students should aim to show their understanding of the core concepts of these courses in the examinations.

Structure, bonding and the p-block elements: 7 Lectures

Dr Andrew Wheatley

This course describes the synthesis, structures and bonding for p-block species such as the borazines, phosphazenes and thiazenes (B/N, P/N and S/N systems). Emphasis is placed on synthetic methodologies, chemical reactivity and understanding how the main group elements bond in the resulting compounds. A range of arguments have been proposed to rationalize the

structure and bonding principles underpinning these systems. Whilst pp bonding in borazines is generally accepted, the bonding in phosphazenes has proved more contentious and it is only recently that covalent bonding models have given way to a combination of more ionic perspectives and negative hyperconjugation. These ideas will be discussed and also applied to sulfur-containing systems. Methods for characterising main group systems will be explored. Students will be expected to extend structure, bonding and analytical concepts to related systems, such as boroxane and siloxane (B/O, Si/O) derivatives.

Topics There are many thousands of inorganic compounds composed primarily of p-block elements. Rather than survey all of them, selected N-containing systems are focused on in order to exemplify concepts in synthesis, structure and reactivity: Borazanes and borazines; adduct formation; the importance of pp bonding in inorganics; substitution by addition elimination reactions; comparisons with organic aromatics. Phosphazenes and phosphazenes; ionic approaches to bonding; reactivity and substitution patterns. The thiazenes; stabilization of weak S/N bonds; insertion reactions. Characterisation of main group inorganic systems; X-ray diffraction and multinuclear NMR spectroscopy.

Introduction to chemical biology: 11 lectures

Prof. Chris Hunter

This course introduces the chemistry of biopolymers, exploring their structure, function and chemistry. The basic chemical concepts that govern non-covalent interactions will be illustrated by reference to the three-dimensional structures of the two most important classes of biomolecules, nucleic acids and proteins. Intermolecular interactions of organic molecules with DNA and proteins will be discussed along with the principles of drug design.

Basic physical organic chemical concepts such as general acid and general base catalysis, transition state theory, free energy profiles, isotope effects etc. will be illustrated by reference to enzyme chemistry. The chemical mechanisms of proteases and other enzymes will be discussed along with the principles of enzyme inhibition and its role in medicine.

This course looks forward to Part II and Part III courses when some of the most exciting recent advances in biological chemistry and chemical biology will be discussed. The approach throughout the course will be based on structure and mechanism – we will not assume any previous biochemical knowledge.

1–6 Non-covalent interactions: van der Waals forces, electrostatics, hydrogen bonding, aromatic interactions, functional group properties, desolvation, hydrophobic effect, entropic effects, cooperativity.

Nucleic acid structure: chemistry of heterocycles, sugars, phosphate esters, the double helix.

Protein structure: chemistry of amino acids, peptides, secondary, tertiary and quaternary structures.

Interactions with small molecules and drug design.

7–11 Thermodynamic and kinetic concepts relevant to biological chemistry including transition state theory, kinetic isotope effects, free energy diagrams. General acid catalysis, general base catalysis, electrophilic catalysis by metal ions, nucleophilic catalysis.

The mechanisms of serine proteases, metalloproteases and other types of proteases.

Enzyme inhibition and its role in medicinal chemistry.

Revision lectures for inorganic chemistry

Dr Sally Boss will give two general revision lectures at 12:00 on 21st May and 23rd May.

Recommended books for Chemistry B

These recommended books should be in your College Library. They can also be consulted in the Departmental Library, and some are available on short-term loan. The designations in brackets [. . .] are the class marks used to identify the books in the Chemistry Department Library, and you should find these texts shelved separately as the *Blue Book* collection in Unit 17, on the right hand side as you enter the library.

Organic chemistry

General organic chemistry

There are a variety of good texts which all cover the first term's material:

Clayden J., Greeves N., Warren S. and Wothers P. *Organic Chemistry*, OUP, 2001. [QD251.O74]

Clayden J., Greeves N. and Warren S. *Organic Chemistry*, 2nd Edn, OUP 2012. (Either edition is acceptable) [QD251.O74]

Carey F. A. and Sundberg R. J., *Advanced Organic Chemistry*, 5th Edn, Springer 2007. [QD251.C37]

Sainsbury M., *Aromatic Chemistry*, Oxford Chemistry Primer No. 4, OUP. [QD331.S25]

McMurry J., *Organic Chemistry*, 7th Edn, Brooks/Cole 2008. [QD251.M36]

Vollhardt K. P. C. and Schore N. E., *Organic Chemistry*, 5th Edn, Freeman 2007. [QD251.V65]

Smith, M. B. and March, J. *Advanced Organic Chemistry: Reactions, Mechanisms, and Structure*, 6th Edn, Wiley, 2007. [QD251.M37]

Structure determination

Williams D. H. & Fleming I. *Spectroscopic Methods in Organic Chemistry* McGraw Hill 6th edition, 2007. [QD272.S6.W55]

Organic Structure Analysis, 2nd Edition Phillip Crews, Jaime Rodriguez and Marcel Jaspars. Oxford University Press, 2010. [QD272.S6.C74]

General inorganic chemistry

Cotton, F. A., Wilkinson, G., Murillo, C. A. and Bochmann, M., *Advanced Inorganic Chemistry* 6th Ed., Wiley (1999). [QD151.C68]

Shriver and Atkins *Inorganic Chemistry*, latest editions. [QD151.S57]

Greenwood N. N. Earnshaw, A. *Chemistry of the Elements*, 2nd Edition. [QD466.G74]

Douglas, B., McDaniel, D. and Alexander, J., *Concepts and Models of Inorganic Chemistry*, 3rd Edition. Wiley. [QD475.D38]

Co-ordination chemistry

M.J. Winter *d-Block Chemistry*, Oxford Chemistry Primer 27, OUP. [QD172.T6.W56]

J. McCleverty *Chemistry of the First-Row Transition Metals*, Oxford Chemistry Primer 71, OUP. [QD172.T6.M33]

J. Keeler & P. Wothers *Chemical Structure and Reactivity* (Chapter. 15) 2nd Ed. [QD471.K44]

Organometallic chemistry

Spessard, G.O. and Miessler, G.L., *Organometallic Chemistry*, Prentice Hall (1996). [QD411.S64]

Elschenbroich, C., *Organometallics*, Wiley-VCH 3rd Ed. (2006). [QD411.E47]

Bochmann M. *Organometallics Volumes 1 and 2*, OUP Primers (1994). [QD411.8.T73.B63]

Crabtree R.H. *The Organometallic Chemistry of the Transition Metals*. 6th Ed. 2014. [QD411.8.T73.C73]

Structure, Bonding and the p-Block Elements

F.A. Cotton, G. Wilkinson, C.A. Murillo & M. Bochmann, *Advanced Inorganic Chemistry*, John Wiley & Sons, 6th Ed, 1999. [QD151.C68]

C.E. Housecroft & A.G. Sharpe *Inorganic Chemistry*, Prentice Hall, 4th Ed. 2012. [QD151.H68]

N.N. Greenwood & A. Earnshaw *Chemistry of the Elements*, Pergamon Press, 2nd Ed. 1997. [QD466.G74]
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C.-I. Branden & J. Tooze, *An Introduction to Protein Structure*, 2nd Edition, 1999. [QP551.B73]
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T. Bugg, *An Introduction to Enzyme and Coenzyme Chemistry*, Blackwell, 1997. [QP601.B84]
C. M. Dobson, J. A. Gerard & A.J. Pratt, *Foundations of Chemical Biology*, Oxford Chemistry Primers, OUP, 2001. [QD415.D63]

7

Practical work

On Wednesday 4th October there are separate introductory talks for Chemistry A and Chemistry B concerning the associated practical course. It is essential that you attend the talk or talks relevant to the course you are taking.

- ***For Chemistry B the talk is at 10:00 in the Bristol–Myers Squibb Lecture Theatre***
- ***For Chemistry A the talk is at 10:45 in the Bristol–Myers Squibb Lecture Theatre***

The practical work in chemistry fulfils two important roles: the first is to illustrate the material presented in the lectures so as to help you understand the concepts and gain familiarity in using them; the second is to develop the skills you will need as an experimental scientist. As chemistry is above all an experimentally based science, it is absolutely essential that you become adept at both performing and interpreting experiments. Chemistry is such a diverse subject that the range of skills needed is quite large; you need confidence in handling the apparatus and reagents used in preparative work, in the use of spectrometers and other instruments to make measurements of physical quantities and in using computers both to analyse data and calculate molecular properties.

When you register you will be assigned a day on which you should attend and complete the practical work; you will be given separate days for Chemistry A and Chemistry B. For Chemistry A the class will be divided into two groups, Group 1 and Group 2. Each Group will complete the same set of experiments and computer-based exercises, but in a different order; the detailed time table is given below.

The practical sessions in the Michaelmas Term are just the afternoon i.e. 13:45–18:00. The experiments have been devised so that you will be able to complete them in this time, but in contrast to the IA practicals, there will not be time for you to write up your account during the laboratory session.

The arrangements for marking practicals will vary slightly from course to course, but the basic idea is that you should have your experiment marked off either before or during your next practical session in the relevant part of the course. All marking will be done in the class by the senior demonstrators.

The marks you obtain in your practical work will be combined with those from the written papers at the end of the year to give your overall mark in Chemistry A or B.

Chemistry A

The main aim of the Chemistry A practical course is to help you to understand the concepts presented in the lectures – especially the key ideas in quantum mechanics which lie at the heart of the course. By doing the experiments and computer exercises you will see these key concepts ‘in action’ and will also see how they can be used in ‘real’ situations.

In addition, as you do the experiments and exercises you will acquire practical skills, such as the use of spectrometers, handling a vacuum line, and making careful measurements with different kinds of apparatus. You will also learn how computers can be used to great advantage in chemistry, for example for analysing data and plotting graphs (using EXCEL), visualising mathematical functions, such as wavefunctions (using Mathematica), and calculating molecular orbitals (using HyperChem).

The course consists of experiments (E) and computer exercises (C) which approximately alternate according to the following time table:

Michaelmas Term

Week no.	1	2	3	4	5	6	7
Group 1	C	E	C	E	C	E	
Group 2		C	E	C	E	C	E

Lent Term

Week no.	1	2	3	4	5	6
Group 1	C	E	C	E	C	E
Group 2	E	C	E	C	E	C

Experiments (E) are held in the Part IB/II Physical Laboratory which is on the first floor of the wing of the building which runs along Lensfield Road; to reach this laboratory turn left on entering the car park end of the building, go through the doors and then up three flights of stairs. Computer exercises are held in the Chemistry PWF (room G30) which is located by the lift on the ground floor at the car park end of the wing of the building nearest to Lensfield Road.

Each session starts at 13:45 pm promptly; it is essential that you are ready to start work at this time as the session will commence with a demonstration. The sessions end at 6 pm, but you may leave earlier if you have completed your work.

You will be given a rough book in which you must record your observations and measurements as you make them. For experiments in the Physical Laboratory the demonstrator will stamp your book and you need to bring it with you when you have an experiment marked off. Your write-up must be presented in the plastic wallets provided.

Write-ups will be marked in the class by the Senior Demonstrator on duty. You must have your write-up of an experiment or exercise marked the next time you do an experiment or computer exercise in the same place. Normally this will be two weeks later. For example, if you are in Group 1 your write-up of the experiment you do in week 2 of the Michaelmas Term will be marked in week 4; likewise if you do a computer exercise in week 5 of the Lent Term, it will be marked in week 7. Senior Demonstrators will be available for marking in week 7 of the Michaelmas Term and weeks 7 & 8 of the Lent Term.

The technician in charge of the Physical Chemistry Laboratory is Chris Brackstone (crb41@cam.ac.uk) and he is assisted by Rafel Cabot Mesquida. The member of staff responsible is Dr Peter Wothers.

Chemistry B

The first aim of the Chemistry B practicals is to teach you the skills needed to synthesise and characterise compounds – this part of the course is entitled Preparative Chemistry. In the first year you have made relatively simple chemical transformations involving one step; the Preparative Chemistry course widens this experience to more complex reactions and experiments in which it is necessary to separate and purify the products. You will also see how to characterise the products of the reactions using spectroscopic tools such as NMR, IR and mass spectrometry. The Preparative Chemistry course will take its examples from across the Periodic Table, from carbon-based organic chemistry through to the diverse chemistry of other non-metallic and metallic elements.

The course will be held in the West end of the ground floor Organic and Inorganic Chemistry Laboratory, whose entrance is on the ground floor by the student pigeon holes. On the day allocated to you, you are required to be in the laboratory and ready to start work at 13:45; the session will commence with a demonstration, and will finish by 18:00. You will attend eight afternoon sessions during the Michaelmas Term, and eight during the Lent Term. You will be given a rough book in which you must record any measurements as you make them.

Your write-up must be presented in the plastic wallets provided and handed in to the technicians at the start of your next practical session. Your demonstrator will mark your scripts and return them to you the following week. You should keep them in a safe place until after the examinations. There is a penalty if you do not hand in your write-up by the following session.

The technician in charge of the class is Helen Jobson (hcj27@cam.ac.uk) and she is assisted by Simon Chapman. The members of staff responsible for the class are Dr Sally Boss, Dr Deborah Longbottom and Dr Bill Nolan.

End of year arrangements

All practical write-ups must be marked before the end of the Term in which the experiments or exercises were completed. You must not accumulate un-marked practicals throughout the Term and then expect to have them marked in the last few days. There will be restrictions and penalties imposed on marking such practicals in the last week.

Any write-ups returned to you after they have been assessed should be kept in a safe place so that they can be reviewed if required.

Practical marks are subject to moderation and/or scaling by the Examiners in order to maintain comparability between different areas and assessors.

Attendance at practical classes is compulsory; you will lose marks from your final total if you do not complete and hand in the accounts of your practical work. If you are unable to attend a practical on the usual day, for example through illness or other good cause, you may come on another day provided that there is sufficient space and equipment available. If you are unable to make up a missed practical session, you should ask your Director of Studies or Tutor to complete a missed practical form (available at www.ch.cam.ac.uk/teaching/resources) and return it to the teaching office; we may be able to award you an average mark for a session that you missed with good cause.

8 Plagiarism

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. 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.

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.

9 Examinations

Chemistry A

There are two three-hour written papers set for Chemistry A, papers A1 and A2. Each paper will contain five questions of equal weight; candidates are required to answer all five questions.

Paper A1 will contain two questions relating primarily to the material presented in the lecture course *Introduction to quantum mechanics*, one question relating primarily to the material presented in the lecture course *Molecular spectroscopy* and two questions relating primarily to the material presented in the lecture course *Symmetry and bonding*. Any question may, however, draw on material from the whole of the Chemistry A course.

Paper A2 will contain three questions relating primarily to the material presented in the lecture course *Molecular energy levels and thermodynamics* and two questions relating primarily to the material presented in the lecture course *Electronic structure and properties of solids*. Any question may, however, draw on material from the whole of the Chemistry A course

Chemistry B

There are two three-hour written papers set for Chemistry B, papers B1 and B2. Each paper will contain five questions of equal weight; candidates are required to answer all five questions.

Paper B1 will contain four questions relating primarily to the material presented in Michaelmas Term and one question relating primarily to the material presented in the lecture course *Introduction to chemical biology*. Any question may, however, draw on material from the whole of the Chemistry B course.

Paper B2 will contain four questions relating primarily to the material presented in Lent Term and one question relating primarily to the material presented in the lecture course *Introduction to chemical biology*. Any question may, however, draw on material from the whole of the Chemistry B course.

The format of the papers is such that you will need to be prepared to answer questions on all of the course. You should also be aware that in the Easter Term there is very little time between the end of the lectures and the examinations. Please take both of these factors into account when planning your programme of supervisions and revision.

In all of the examinations you will be provided with a Data Book which contains a simple Periodic Table, values of physical constants, certain mathematical formulae and definitions and selected character tables. You will be provided with a copy of the Data Book when you register for the course (accessible on line at www.ch.cam.ac.uk/teaching/data-book). You may take (unassembled) molecular models into the examinations.

As the course has been altered and revised over the years, not all of the questions on past Tripos papers are directly relevant. However, each lecturer will indicate which, if any questions, are relevant from previous years. A selection of recent past papers are available from the relevant sections of Moodle (www.vle.cam.ac.uk), and suggested answers to questions more than five years old are also available.

The marks obtained on the written papers are combined with marks obtained from the assessed practicals: usually 80% of the final mark is for the theory and 20% for the practicals.

The Senior Examiner for Part IB Chemistry A is Dr J. H. Keeler and for Chemistry B is Dr P. D. Wothers.

How to approach the examination

As you will have discovered at the end of last year, Cambridge written examinations are very different in style to those you will have become used to at school or college. As you prepare for your second round of tripos examinations, it is a good idea to reflect on your experience from last year, and draw what lessons you can from it. It is absolutely vital that, ahead of the examinations, you familiarize yourself with the style of the questions and spend some time practising some past papers.

Remember that Cambridge examinations are designed to be challenging to even the best students – the average mark for a Chemistry written paper is about 65%, very few students achieve marks of over 80%, but there will be significant numbers with marks below 50%.

All of the questions involve solving a problem of some kind, and to do this successfully you will need both factual information and – most importantly – an understanding of the underlying chemical principles which are being applied in the question. You can expect the questions to be similar in style to those you have done as exercises associated with the lecture course or to past exam questions, but the questions you will be confronted with in your examination will certainly not be the same as those you have seen before. You certainly cannot ‘learn’ the answers to the questions: you will need to work them out using your understanding of chemical principles.

Many students find the biggest difficulty with a Cambridge examination is that they run out of time. This is a reflection of the difficulty of the questions, which may not only require you to write

more than you are used to, but may also need quite a bit of thought before you can start to answer them.

It is for this reason that you need to be very careful about dividing your time equally between the questions on the examination paper. On each Chemistry paper there are five questions to answer, each with equal weight, so 36 minutes should be allocated to each. All those involved in marking examination papers will tell you that the greatest number of marks are achieved earlier in the early stages of answering a question. Therefore, carrying on beyond 36 minutes in the hope that 'the answer' will suddenly pop out, and hence gain you the final few marks, is not a good strategy. Far better to move onto the next question and gain the straightforward marks for this.

Most questions are subdivided into parts, and the approximate division of marks is given at the end of the question. It is important to pay attention to this. If a part receives 10% of the marks, then clearly only a very short answer is expected – not a page of explanation. No matter how much you write, the maximum number of marks will still be 10%.

In setting the questions the examiners will have in mind a particular answer. However, full credit is given for any answer which the examiner deems reasonable, even if it is not the answer that he or she originally had in mind – there is no one right answer.

For many questions, a well-constructed and labelled diagram, accompanied by a few well thought out sentences, is all that is required, and is indeed the best way to structure an answer.

If you make a mistake in your answer, simply cross it out and carry on; under no circumstances should you use 'TippEx' or other such products. It may be that you have crossed out the 'right' answer, or at least a valid approach, in which case the Examiner may be inclined to give some credit. On the whole, the examinations are marked in a generous way; there is no negative marking.

Finally, you should try to write as legibly and clearly as you can, simply because this will help the examiner to read and mark what you have written. Use a good quality black or blue pen that makes a medium width line (not a very fine line, which is harder to read). You may draw diagrams in pencil and use colour for these, if it seems helpful. However, the main part of your answers should be written in pen. Do not crowd the page with text and diagrams – rather, leave some space so as to improve legibility.

If you want further advice on how to approach examinations, then you should approach your Director of Studies or supervisor.

Criteria for assessment

At the end of the year you will be awarded a mark and a class, separately for Chemistry A and Chemistry B. The Natural Sciences Tripos Committee gives specific guidance on the relationship between marks and classes, and on the expected distribution of candidates amongst the classes.

The final mark will be made up of 20% derived from the marks awarded in the practical course and 80% from the marks achieved in the end of year examination. The marking scheme used in the practical course is not designed to differentiate strongly between candidates, and as a result the spread of marks is quite narrow and the average mark is quite high. Candidates who do not complete the experiments will, therefore, put themselves at a significant disadvantage.

In contrast, the examination is a strong discriminator. In the examination marks are awarded for any reasonable answer – it is not necessary to give the 'expected answer' in order to gain credit. In addition, marking is on the whole quite generous, and there is certainly no negative marking.

10

Disclosure of examination marks

The marks which are disclosed (via *CamSIS*) are those for each of the papers, a total mark for the continuously assessed component of the course and the final overall total and class. Please note that the marks from the continuously assessed component may be scaled by the Examiners, and the overall mark may also be subject to scaling, as required by the Natural Sciences Tripos committee. In addition you will be notified separately of your question-by-question marks.

11

Chemistry teaching website

You can find up-to-date information on the course and other related matters from the teaching website: www.ch.cam.ac.uk/teaching.

Handouts and other course materials will be posted on *Moodle*: 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@ch.cam.ac.uk.

12

Chemistry Consultative Committee

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

13

Further details of the department

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 during the registration process for the practical classes we will have been able to programme your card for appropriate access. If you find that your access rights are different to others in your year group, please contact Susan Begg (smb28@cam.ac.uk) who can make authorised changes. You will find you have slightly different access rights from last year, but if your card does not let you into the building you should let us know right away. Please note that undergraduates will *not* be given access to research areas. If you need to meet supervisors and so on, you will need to arrange for them to meet you in a general access area. Do make sure you know who they are and how to contact them, so that Security can help you locate them if necessary.

Your card will give you access to the building from 09:00–20:00 on weekdays, and from 09:00–13:00 on Saturdays. 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. Should this happen use one of the emergency red telephones and contact 36330 or Central Security on 101 to let them know where you are.

www-library.ch.cam.ac.uk

The Departmental Library, which is located in the Centre for Molecular Informatics (linked to the main building), is available for you to use when the department is open. You will need your University Card to gain access to the library. Evening and weekend library access is available to Part IB Chemistry students. Please ask your Director of Studies to apply in advance on your behalf, specifically confirming your status as a Part IB Chemistry student, in an email to library@ch.cam.ac.uk. Eligibility for access to the Library and details of borrowing rights can be found on this website: www-library.ch.cam.ac.uk/access-library.

The *Blue Book* collection of core texts is shelved in Unit 17, on the right hand side as you enter the library. Most of this collection is for short loan (three days) or for reference only. The rest of the book collection is shelved on the wall to the left and on the shelves behind the periodical display. All Chemistry books are listed on iDiscover, the online catalogue for the libraries of the University; www.idiscover.lib.cam.ac.uk. There is a dedicated computer in the library for searching the catalogue. Part IB students may borrow from the library and should call in to the library office to set up a borrowing account on the automated system.

Short undergraduate induction sessions are held in October and you are welcome to attend. These sessions will be advertised by email. If you would like to recommend any resources, make suggestions or discuss anything related to the Library, please contact the student representative on the Committee for the Library and Scholarly Communication www-library.ch.cam.ac.uk/committee-library-and-scholarly-communication or email the Library directly on library@ch.cam.ac.uk.

It is forbidden to bring food into the Library. The only drink permitted in the Library is water in a container with a non-spill cap.

Photocopying, printing, scanning, and computing facilities

The library has 20 PCs and 2 Macs which are hosted on the MCS (Managed Cluster Service) network and print jobs can be sent from these to a *multifunctional device* (MFD) situated in the small room next to the Library Office. The MFD offers colour printing, as well as photocopying and free scanning. Online payment for printing and photocopying on this machine is made through the *common balance* scheme, there is more information at

www.ucs.cam.ac.uk/desktop-services/ds-print/paying-for-ds-print

There is also a traditional photocopier by the lift on the second floor of the Lensfield Road side of the Department and photocopy cards for this machine can be purchased from the Library Office. Computers and MFDs which are also attached to the MCS network are available in the room G30 (by the lift on the Lensfield Rd side of the building), and in the Part IB/II Physical Chemistry Laboratory. When practicals are being run, access to the computers in G30 and the Physical Laboratory may be restricted.

If you are intending to specialise in chemistry in the third (and possibly fourth) year you should taken both Chemistry A and Chemistry B so as to have the broadest grounding in chemical topics. A route is provided within Part II Chemistry for those who have only taken Chemistry B in Part IB, but it is important to realise that by taking this route you will have a more restricted range of options. If you have only taken Chemistry A it may be possible to continue with Part II, but you will need to undertake some directed study over the preceding vacation.

You should note that in order to proceed to Part III (the fourth year) you need to achieve at least a II.1 in Part II Chemistry.