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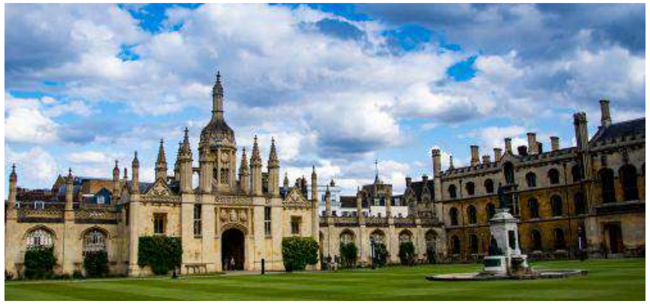

Chemistry

SYLLABUS OVERVIEW

16-18 YEARS OLDS

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About Immerse

Immerse Education is an award-winning academic summer school provider offering programmes for 16-18 year olds in centres of academic prestige.

The aim of these programmes is to provide participants with academically challenging content that develops their understanding of and passion for their chosen discipline. Through 40 hours of academic sessions, the programmes also offer young students unique and valuable insights into what it would be like to study their chosen subject at university.

This Syllabus Overview provides a summary of the topics and subject areas that participants can encounter during their studies with Immerse. It has been carefully created by our expert tutors who are current members of world-leading universities, and who have experience in teaching undergraduate students.

Academic Sessions

The academic sessions at Immerse are arranged into modules to enable participants to explore a broad range of topics over the course of two weeks. The modules included in this syllabus overview are indicative but not prescriptive.

Tutors are encouraged to include their own specialisms and also focus on any particular areas of interest expressed by participants within the class. They may choose to provide further detail on a specific topic, or they may include new material and information that builds on the knowledge already developed during the programme.

Personal Project

Each programme includes an element of individual work, generally termed the 'Personal Project'. This can take many forms but is commonly an essay or presentation delivered on the final day of the programme. Participants will receive feedback on this work which may also be mentioned in the participant evaluation which is provided in writing by the tutor once the programmes have ended.

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Preparatory work

Some tutors may ask participants to complete some preparatory work, such as reading or a series of exercises in advance of the programme. Participants are strongly encouraged to complete this work since it will be included in the opening sessions of the programme. Any preparatory tasks will be provided in advance of the programme directly to the participant.

Academic Difficulty

As all of our programmes are designed to provide a unique introduction to advanced material, the syllabus will be academically challenging at times.

This is something to be excited about and all of our tutors will encourage and support participants throughout the programme. Immerse Education aims to develop every participant regardless of ability, and our tutors will adapt their teaching to individual needs.

Aim of the Chemistry Programme

The Immerse Education Chemistry programme is designed to build upon the foundation of knowledge that participants have already gained in a traditional classroom environment and highlight how this can be used to inspire further study at university. Participants are encouraged to explore new material in-depth and to form independent and considered opinions and ideas based on sound academic knowledge and research. By the end of the programme, participants will have a good understanding, not only of university-level content, but also the variety of degree programmes available in subjects related to chemistry. Beyond this, participants will also explore the career opportunities available to graduates in this field.

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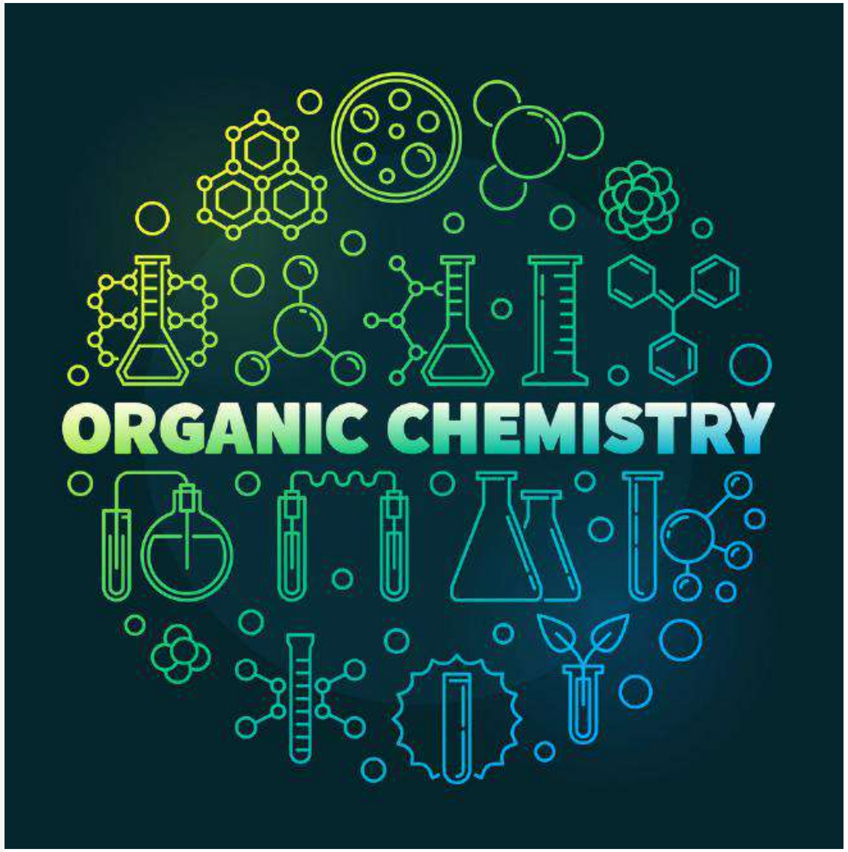
Atomic Structure and Periodicity

In the first part of the course, participants take a closer look at the atom, discussing some of the earlier models of atomic structure. These seminal works, and others, led to the discovery of subatomic particles (protons, neutrons and electrons), and their corresponding properties. The class defines key terms relating to the atom, which form the foundation of the chemistry course. The tutor also introduces the mole concept and participants use it to perform important chemical calculations. Finally, participants analyse the modern periodic table (a concise arrangement of chemical elements based on their atomic structure) and discuss the trends that arise from this ordering.

Quantum Mechanics

The classical description of the atom (the Bohr Model) provided key recipes for computing the energy levels of hydrogen-like atoms. Around the early 20th century there were several key discoveries that could not be explained within the classical description of the atom (particularly, the Bohr Model). These observations and contradictions of the established theories eventually led to the introduction of quantum mechanics, paving the way for our modern understanding of the atom structure and constituents. In this session, the four quantum numbers are introduced, and participants collaborate to provide key comparisons between the quantum mechanical and classical models of the atom.



Organic Chemistry and Bonding

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Participants explore covalent bonding in more detail and define key terms, such as electronegativity. The resonance structures of covalent bonds in molecules and polar covalent bonds are discussed. Other bonding, namely ionic and metallic bonding are also explored, and participants predict the bonding between elements based on their structures, valence electrons and position in the periodic table. This topic utilises key concepts covered in earlier topics and also describes giant covalent compounds and their properties. In the second half of the session, participants are introduced to organic chemistry. Discussion centres around the structures, properties and chemical reactions of alkanes and alkenes. Nucleophilic substitution and electrophilic addition reactions are thoroughly outlined.

Thermodynamics

Lord Kelvin said, ‘Thermodynamics is the subject of the relation of heat to forces acting between contiguous parts of bodies, and the relation of heat to electrical agency’. In 1840, the field of thermodynamics was expanded to encompass the study of energy transfers in chemical reactions by the German scientist, Hess. In this module, the 1st and 2nd laws of thermodynamics, and the concepts of enthalpies and entropies of chemical reactions are introduced. Hess’s law of chemical thermodynamics is discussed as well as the use of the heat of formation for forming compounds. Participants also discuss more abstract, but engaging, ideas, such as spontaneous and nonspontaneous reactions.

Kinetics

A kinetics experiment measures the rate at which the concentration of a substance taking part in a chemical reaction changes with time. The rate law is the relationship between the rate and the concentration, which are related by a proportionality constant, 'k', called the rate constant. We use the above to introduce more advanced topics, such as chemical equilibrium, Le Chatelier's principle, integrated rate laws, reaction mechanisms and Arrhenius equation. We work through the derivations in a step-by-step manner and consolidate concepts by referring to practical examples, such as the Haber process, and simple chemical reactions performed in the laboratory.

Acids and Bases

Svante Arrhenius defined acids as substances that dissociate in water to produce hydrogen ions and bases as substances that release hydroxide ions in water. Brønsted and Lowry independently defined acids as proton donors and bases as proton acceptors. On the other hand, G. N. Lewis defined acids as electron pair acceptors and bases as electron pair donors. All these definitions are useful and help us understand the reactions of acids and bases (i.e., neutralisation reactions). Here, participants work through other concepts such as strong vs weak acids/bases and pH. Acid/base dissociation constants, which are special types of equilibrium constants are also discussed as well as buffers.

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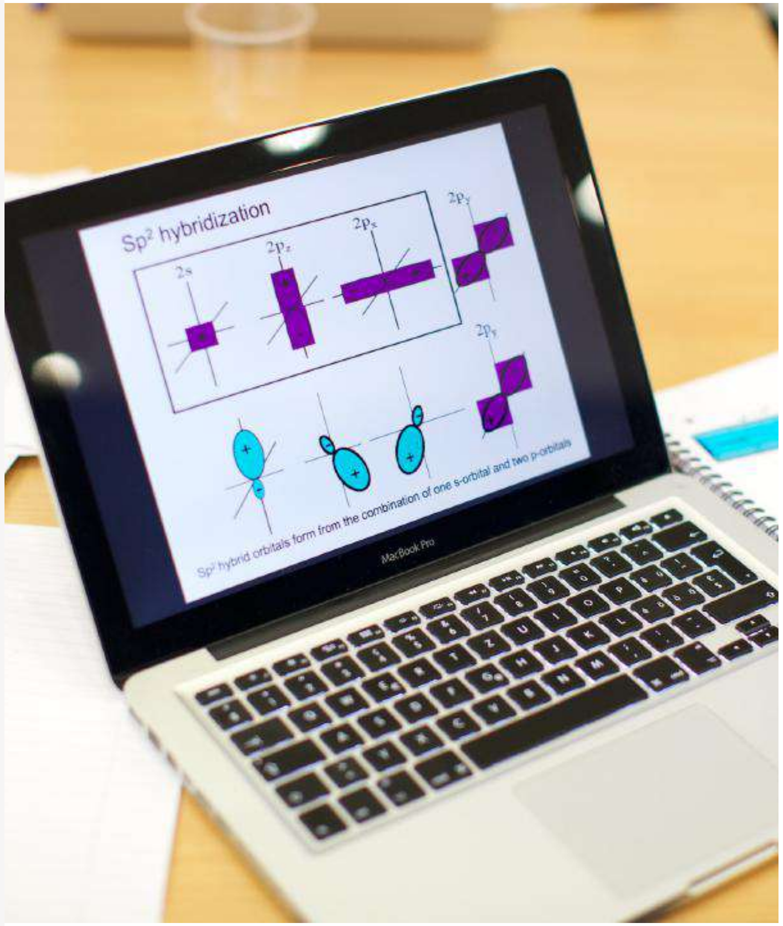

Compounds, Hybridisation and VSEPR Theory

Twenty years prior to the development of quantum mechanics, G. N. Lewis introduced an organising principle in bonding known as the Lewis structures, which helps predict the covalent bonding pattern of atoms. It is also a means of visualising the atoms in a bond, and allows us to conceptualise bonding between different molecules. Molecular orbital theory (based on quantum mechanics) and hybridisation (combining of atomic orbitals) are other indicators of how molecules are structured, and provide a more detailed look into the mechanisms they may use to form compounds. Participants will also employ the Valence Shell Electron Pair Repulsion (VSEPR) theory to determine the angular inclinations of molecular structures.

Experimental and Computational Techniques

We introduce some of the common experimental and computational approaches employed to probe chemical properties of molecules and reactions. Firstly, we explore methods such as mass spectroscopy, infrared spectroscopy and nuclear magnetic resonance (NMR) spectroscopy. We also discuss various separation techniques, as well as diffraction techniques – which are largely used for structure determination. Secondly, we introduce the concept of a potential energy surface and describe how geometry optimisation techniques can be used to explore that surface. We also familiarise ourselves with the various levels of accuracy in computational chemistry, and so contrast ab initio and molecular mechanics calculations.

Sustainable Chemistry

A biofuel is a fuel that contains energy from geologically recent carbon fixation and are produced from living organisms, for example, in plants and microalgae. These fuels are made by a biomass conversion (biomass refers to recently living organisms, most often referring to plants or plant-derived materials). This biomass can be converted to convenient energy containing substances in three different ways: thermal conversion, chemical conversion, and biochemical conversion. Researchers are very interested in developing new catalysts for removing harmful greenhouse gasses from the atmosphere. Nature has already figured out how to accomplish this. Certain microbes 'live on' CO or CO2, utilizing enzymes with metal cofactors that facilitate carbon fixation reactions.

Nanoscience and Nanotechnology

In 1959, Richard Feynman gave a lecture at CalTech called, 'There's Plenty of Room at the Bottom'. In it, he was the first to talk about the possibility of directly manipulating atoms on the atomic scale. Sixty years later, we have made incredible advances in nanotechnology; silver nanoparticles are used in Nike socks as an antibacterial so that you no longer need to wash your socks (this is, however, not advisable!), bulletproof vests contain carbon nanofibers making them stronger and more lightweight.

This topic will encompass the four big questions on everyone's mind: What is Nanotechnology? How does it work? Why do we need it? What are the next steps?

Personal Project

Throughout the fortnight, participants will be working on their own personal project. Having been provided with a brief, participants should research and prepare a presentation for their peers. This will build upon an aspect of the theory that they have learnt over the course of the programme and is also an opportunity to showcase the academic research skills they have developed. The presentation is followed by questions from the audience and wider class discussion of particular points of interest. The tutor may also include feedback about the presentation in the written evaluation which is sent to participants after the programme has ended.

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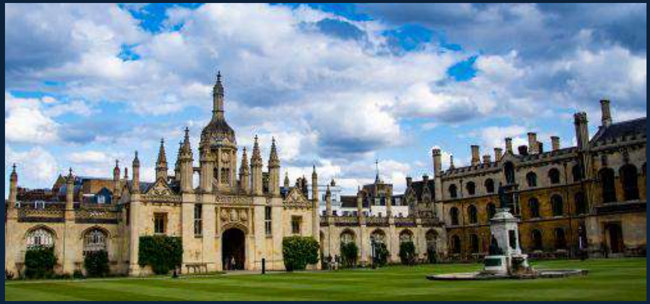


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