

MODULE M

PHYSICAL CHEMISTRY IN ACTION

(MODULE ORGANISER: DR A C JONES)

Dr. Barran

Mass Spectrometry (7)

Dr. Mount

Sensors (5)

Drs. McDougall/Mount/Jones

Microscopy and Imaging (10)

Dr. Dryden

Biomolecular Systems (8)

MASS SPECTROMETRY

7 Lectures

Dr. P. Barran

AIMS

The aim of this course is to provide an overview of modern mass spectrometric instrumentation and techniques. A particular emphasis will be placed on mass spectrometry based methods which determine the structure of ions in the gas phase.

The basic principles of different types of ion sources and some of the most common mass analysers will be reviewed. Methods of ion detection and computer-aided data processing will also be discussed. The characterisation of compounds through dissociation and association reactions will be covered using recent examples. This course will discuss novel techniques of analysing the structure of proteins in a solvent free environment, both from a 'bottom-up' and 'top-down' perspective.

This course will build upon the Chemistry 3 lecture course on "Mass Spectrometry" given by Dr Campopiano. Knowledge of the fragmentation patterns associated with electron impact ionisation, and chemical ionisation, as well as the ground rules for spectrum interpretation, covered in this earlier course will be assumed.

An attempt will be made to illustrate current practice with case studies on the analysis of biomolecules drawn from the research literature. The course will be supported with web-based supplementary resources and problems.

SYNOPSIS

1. **Mass Spectrometry:** Ionisation and fragmentation.
2. **Ion Sources and Methods of Ionisation:** Electron impact ionisation (EI). Chemical ionisation (CI). Matrix assisted laser desorption ionisation (MALDI). Electrospray ionisation (ESI). Fast atom bombardment (FAB). Field ionisation (FI) and field desorption (FD). Plasma desorption (PD), Inductively coupled plasma (ICP)
3. **Mass Spectrometric Analysers:** Mass resolution. Mass measurement accuracy. Quadrupole mass analyser. Ion trap analyser. Time-of-flight (TOF) analyser. Magnetic and electromagnetic analysers. Ion cyclotron resonance and Fourier transform mass analysers.
4. **Ion Detection, Data Recording and Processing**
5. **Tandem Mass Spectrometry (MS/MS):** Collision activated ion decomposition (CAD or CID). MS/MS applications.
6. **Fragmentation Patterns:** Spectrum interpretation.
7. **Proteomics – Peptide Mass Fingerprinting,** bio-informatics
8. **Protein Structure in the gas phase – Ion Mobility and HD Exchange**

READING

1. "Mass Spectrometry", J. Barker, (Wiley)
2. "Mass Spectrometry: Principles and Applications", E. de Hoffman, J. Charette and V. Stroobant, (Wiley)
3. "Mass Spectrometry of Proteins and Peptides" - J. R Chapman (Humana)

www.chem.ed.ac.uk/bunsen/analysis.html

www.ionsource.com/

www.chem.arizona.edu/facilities/msf/onLine/resource.html

www.wiley.com/wileychi/ms/

SENSORS

5 Lectures

Dr. A. R. Mount

AIMS

The aims of this course are:

- to illustrate the need for new chemical sensors across a wide range of applications
- to consider the essential elements of the sensor system; sensing, transduction and signal measurement
- to explore how each of these elements can be optimised to enable detection of a particular analyte to the appropriate sensitivity and selectivity
- to demonstrate by example how this strategy has been and can be used to further develop novel sensing systems

LEARNING OUTCOMES

By the end of this course you should be able to understand the modes of operation of the various classes of chemical sensor, their advantages and disadvantages and their suitability to any given application.

SYNOPSIS

1. Sensors; traditional methods of sensing; disadvantages of using traditional methods e.g. health and safety, need for automation, detection of novel analytes.
2. Chemical sensors; importance of such factors as sensitivity, selectivity, dynamic range, cost, reproducibility, location; importance of factors to each application
3. The essential elements of chemical sensors; sensing, transduction and signal measurement.
4. Transduction and signal measurement methods; electrochemical, optical, piezoelectric, thermal; advantages and disadvantages of each method for measurements.
5. Chemical sensing elements; design of molecular recognition systems by chemical synthesis; integration with transduction methods; use of natural sensing elements, biosensor systems.

RECOMMENDED READING

1. Chemical Sensors, R.W. Cattrall, OUP, 1997
2. Faraday Discussion 107, 1997 (Quartz Crystal Microbalance)

MICROSCOPY AND IMAGING

10 Lectures

Drs. A. C. Jones, G. S. McDougall and A. R. Mount

AIMS

To introduce light, electron and scanning probe microscopies and illustrate their application in chemistry.

SYNOPSIS

1. **An introduction to the physical basis of optical, electron and scanning probe microscopies:** light microscope elements and systems, imaging, confocal microscopy, scanning near field optical microscopy, the diffraction limit in optical microscopy, beating the diffraction limit, transmission electron microscopy, scanning electron microscopy, scanning tunneling microscopy (STM), atomic force microscopy (AFM) (electret based micropositioning devices, elastic electron tunneling, surface force, STM/AFM instrumentation)
2. **Applications:** Fluorescence microscopy and imaging, (Introduction to fluorescence, Fluorescent probes, Confocal fluorescence microscopy, Multiphoton excitation fluorescence microscopy, Fluorescence lifetime imaging), Infrared and Raman microscopy, In situ studies of surface chemistry and catalysis by SPM

LEARNING OUTCOMES

By the end of this course you should:-

- Have an appreciation of the range of imaging techniques available and a knowledge of their relative merits and areas of application.
- Have an understanding of the physical basis of each of the methods introduced and be aware of the essential features of the instrumentation associated with each.

RECOMMENDED READING

'Light and Electron Microscopy', Elizabeth M. Slater, Henry S. Slater, Cambridge University Press, 1992.

'Fluorescence Imaging, Microscopy and Spectroscopy'; X. F. Wang and B. Herman (eds), Wiley 1996.

BIOMOLECULAR SYSTEMS

10 lectures

Dr. D. Dryden

AIMS

To introduce the application of physical chemistry to understand the behaviour of complex biological macromolecules, including protein molecular motors, both in a test tube and inside a living cell.

SYNOPSIS

1. Protein dynamics. Thermodynamic and kinetic aspects of protein structure. Experimental evidence for protein dynamics. The protein folding problem.
2. The intracellular environment and the behaviour of macromolecules. Size, shape and concentration of macromolecules within living cells. Macromolecular crowding.
3. Interactions between macromolecules with emphasis on protein-DNA interactions.

LEARNING OUTCOMES

By the end of this course you should understand the dynamic nature of proteins and DNA and the importance of dynamics inside living cells. You should also be familiar with a range of techniques used to analyse biological macromolecules including fluorescence spectroscopy and single molecule imaging.

READING

Literature references will be given during the course. The following texts should also be consulted.

“Biophysical chemistry”, volumes 1-3. CR Cantor & PR Schimmel (WH Freeman & Co.)

“Molecular biophysics”. M. Daune (OUP)

“Structure and mechanism in protein science” A Fersht (WH Freeman & Co.)

“Principles of physical biochemistry”. KE van Holde, WC Johnson & PS Ho (Prentice Hall)