UAB
Universitat Autònoma de Barcelona

Molecular Imaging in Biomedicine

2026/2027

Code: 107986
Credits: 6

Degree programme	Type	Course
Biochemistry	OP	4

Contact lecturer

Name : Ana Paula Candiota Silveira

Email : anapaula.candiota@uab.cat

Teaching staff

Nathalia Varejao Nogueira

Ana Paula Candiota Silveira

Josep Bartomeu Cladera Cerdà

Group languages

You can consult this information at the end of the document.

Prerequisites

The students must have attained the learning skills of the courses: Basic Instrumental Techniques and Advanced Instrumental Techniques.

Objectives

Much of the scientific knowledge of Nature is based on the study of various phenomena of absorption and emission that occur when electromagnetic radiation interacts with matter. In biosciences, spectroscopic techniques are used very often, but unfortunately many professionals are mere users that simply apply these techniques without having a well-founded scientific and technical knowledge to take advantage of all the possibilities of the different spectroscopies. This course will study in depth the scientific and technical foundations of the major spectroscopic techniques of interest for Biochemistry and Molecular Biology: absorption spectroscopy in ultraviolet and visible regions; fluorescence spectroscopy and chemiluminescence; nuclear magnetic resonance spectroscopy; positron emission tomography; spectroscopy in the infrared region; circular dichroism. In all cases, the instruments and analytical and structural applications in life sciences will be studied in detail.

Learning outcomes

- CM35 (Review the applications of emerging technologies associated with synchrotron radiation and nanotechnology in the area of biochemistry to offer innovative solutions for societal needs.) Review the applications of emerging technologies associated with synchrotron radiation and nanotechnology in the area of biochemistry to offer innovative solutions for societal needs.

- CM36 (Explain the fundamental aspects of a topic in the field of biophysics orally.) Explain the fundamental aspects of a topic in the field of biophysics orally.
- CM37 (Integrate knowledge from biochemistry and molecular biology with emerging technologies associated with synchrotron radiation and nanotechnology.) Integrate knowledge from biochemistry and molecular biology with emerging technologies associated with synchrotron radiation and nanotechnology.
- KM39 (Describe the physical foundations and applications of spectroscopic and microscopy techniques used in structural analysis and in the study of biomolecules and biological membranes.) Describe the physical foundations and applications of spectroscopic and microscopy techniques used in structural analysis and in the study of biomolecules and biological membranes.
- SM39 (Use digital resources to process data from spectroscopic and microscopy research, and to calculate specific parameters.) Use digital resources to process data from spectroscopic and microscopy research, and to calculate specific parameters.
- SM40 (Apply spectroscopy and microscopy techniques to the study of biomolecules, biomembranes and nanoparticles.) Apply spectroscopy and microscopy techniques to the study of biomolecules, biomembranes and nanoparticles.
- SM41 (Apply general and specific safety standards when performing spectroscopy or handling biological materials and nanoparticles.) Apply general and specific safety standards when performing spectroscopy or handling biological materials and nanoparticles.

Contents

BLOCK 1

1. Spectroscopy and infrared microscopy

1.1 The interaction of infrared radiation with molecules. Vibrational modes.

1.2. Michelson's interferometer. Principles, experimental design and Fourier transform. The interferogram. The apodization.

1.3 Practical aspects: spectra in aqueous suspension. Advantages of FTIR spectroscopy.

1.4 Mathematical techniques for band resolution: derivation, deconvolution and band adjustment.

1.5 Proteins. Vibrational bands associated with the amide bond and secondary structure of proteins. Difference spectroscopy.

1.6 Biological lipids and membranes. Thermotropic studies.

1.7 Infrared Microscopy and Synchrotron Light.

1.7.1 Studies by IR microscopy of cell cultures as models of human pathologies.

1.7.2 Studies by IR microscopy of brain tissues in animal models of Alzheimer's disease.

1.7.3 Studies by IR microscopy of human brain tissues in Alzheimer's disease.

2. Circular dichroism (CD)

2.1 Principles. Optical activity. Ellipticality. The spectrum of circular dichroism.

2.2 Instrumentation.

2.3 Secondary protein structure. Examples.

BLOCK 2

3. Nuclear magnetic resonance (NMR) spectroscopy

3.1. Introduction. Physical bases of the resonance phenomenon: nuclear spin, resonance condition. Radiofrequency pulse excitation, NMR signal detection (FID) and Fourier transform.

3.2. Experimental design, instrumental issues: magnet, coils for disturbing systems and their detection. Signal / noise quotient.

3.3. Parameters that characterize the NMR spectrum of a biological sample. Resonance area. Chemical displacement. Multiplicity. Relaxation: relaxation times T2 and T1.

3.4. Magnetic resonance imaging (MRI). Fundamentals. Magnetic field gradients and concept of selective excitation, concept of space k, contrast to MRI images. Single / multivoxel magnetic resonance spectroscopy and metabolic patterns.

3.5. Biomedical applications of NMR. Accessible information:morphological and functional anatomy. Applications to preclinical and clinical studies.

4. Positron emission tomography (PET)

4.1. Physical principles. Radioactive Decay. Annihilation process. Photon detection. Attenuation.

4.2. Experimental design. Detection system. Image reconstruction

4.3. PET radio tracers: Characteristics of positron emitting radionuclides. Properties of radiopharmaceuticals and metabolic activity. Cyclotron.

4.4. Applications in oncology, neurology and cardiology. Development of labeled compounds that measure the activity of specific receptors.

BLOCK 3

5. Ultraviolet and visible absorption spectroscopy

5.1. Physical principles and experimental design.

5.2. Absorption spectrophotometry.

5.3. Applications: study of proteins, nucleic acids and other biochemical chromophores.

5.4. Influence of the environment on the absorption spectrum.

6. Fluorescence and chemiluminescence spectroscopy

6.1. Physical bases: internal conversion, vibrational relaxation, emissive and non-emissive relaxation.

6.2. Experimental design: problems associated with fluorescence measurements, strategies and components that increase sensitivity.

6.3. Fluorescence microscopy: principles, instrumental setup, and biochemical applications.

6.4 Phenomena that may affect fluorescent emission: effects of molecular environment and solvent, collisional quenching of fluorescence, polarization, formation of excited dimers (excimers), energy transfer.

6.5. Application to the structural analysis of macromolecular systems: intrinsic and extrinsic fluorophores, accessibility, rotational diffusion, distance measurement. Applications to Biochemical analysis, Molecular Biology and Cell Biology.

6.6. Physical bases and applications of other emitting phenomena: chemiluminescence and bioluminescence.

Learning activities and methodology

Title	Hours	ECTS	Learning outcomes
Tutorials	6	0.24	CM35, CM37, KM39, SM40
Problems/scientific works	30	1.2	CM35, CM36, CM37, KM39, SM39, SM40
Lectures	36	1.44	CM35, CM37, KM39, SM39, SM40
Grup activity: preparation of a seminar about problems/scientific works	6	0.24	CM36, KM39, SM39, SM40
Laboratory work	9	0.36	CM36, CM37, KM39, SM40, SM41
Individual study	55.5	2.22	CM35, CM36, CM37, KM39, SM40

Theory. The teachers will explain most of the course content with the support of material that will be available to students in the Virtual Campus (VC). To be able to follow correctly the explanations, students should bring the VC material to the class. The theory sessions address the conceptual parts of the course. Other parts of the course must be approached autonomously by students. The teachers will indicate exactly which topics will have to be studied this way and the material to be used.

The contents of the subject will be taught in three blocks: Block 1- Infrared Spectroscopy / Microscopy, Circular Dichroism ; Block 2- Nuclear Magnetic Resonance Imaging, Positron Emission Tomography (PET); Block 3-UV/Vis spectroscopy, Fluorescence, chemiluminescence .

Problems. The teachers will propose problems/scientific works related to the Spectroscopy of Biomolecules. The concrete way of developing each kind of problem/scientific work will be indicated in class or in the VC. Students will form small groups to solve and make oral and written presentations of proposed problems/scientific works.

Laboratory work. To acquire technical knowledge on the existing instruments related to spectroscopy, laboratory work will be done in various Scientific-Technical Facilities of the UAB: Laboratory of Luminescence and Spectroscopy of Biomolecules; Microscopy Facility; Magnetic Resonance Facility; Laboratory of Biophysics.

Annotation: within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Assessment

Continuous assessment activities

Title	Weight	Hours	ECTS	Learning outcomes
Final exam	50%	3.75	0.15	CM35, CM37, KM39, SM39, SM40
Assessment of the presentation of problems/scientific works and/or submission of practical reports	30%	2.25	0.09	CM35, CM36, CM37, KM39, SM39, SM40
Assessment of laboratory work	20%	1.5	0.06	CM35, CM37, KM39, SM39, SM40, SM41

Each block of the subject (1- Infrared and circular dichroism; 2- NMR/PET; 3- UV/Vis, fluorescence and chemiluminescence) will be evaluated independently according to the three assessment elements:

(1) Public presentation of problems/scientific papers in class (group assessment) and/or submission of reports on problems/scientific papers (group assessment): maximum 3 points (30%)

(2) Assessment of participation in practical sessions and/or submission of practical reports: maximum 2 points (20%)

(3) Theoretical content examination: maximum 5 points (50%)

There will be two partial examinations covering the theoretical contents:

First partial examination: Block 1

Second partial examination: Blocks 2 and 3

In the case of the second partial examination, the test will include contents from Blocks 2 and 3. The questions corresponding to each block will be graded independently, resulting in a specific examination mark for each block.

A block will be considered passed when a grade of 5.0 or higher (out of 10) is obtained. To pass the course, all three blocks must be passed individually.

The final course grade, provided that all three blocks have been passed, will be the average of the grades obtained in the three blocks, with each block grade calculated using all assessment components corresponding to that block

The dates for examination review sessions will be announced at least 2 days in advance.

Students who have not passed the course (grade below 5.0 out of 10 in any of the three blocks) must take the resit assessment for the block(s) not passed.

The resit assessment for Blocks 1, 2 and 3 will be conducted independently, so students will only be required to retake the block(s) that have not been passed.

To be eligible for the resit assessment, students must previously have been assessed through activities accounting for at least two-thirds of the total course grade. Therefore, students will receive the grade "Not Assessable" when the assessment activities completed represent less than 67% of the final course grade.

The resit grade will be calculated by combining the resit examination grade with the grades obtained in the remaining assessment activities.

Attendance at practical sessions is mandatory. Students will receive the grade "Not Assessable" if their absence exceeds 20% of the scheduled practical sessions.

Single evaluation

The single evaluation will consist of a single synthesis testthat willassess the content of the entire theory program of the subject. The test will include multiple-choice questions and/or open-ended questions. The grade obtained in this synthesis test will account for 70% of the final grade of the subject.

The evaluation of practical activities and the public presentation of problems/scientific works in class (group evaluation) and/or the submission of reports on problems/scientific works (group evaluation) will follow the same process as continuous evaluation. The evaluation of participation in practical activities will account for 10% of the final grade of the subject, and the public presentation of problems/scientific works in class (group evaluation) and/or the submission of reports on problems/scientific works (group evaluation) will account for 20%.

The single evaluation test will take place on the same date as the final test of continuous evaluation, as indicated in the calendar, and the same recovery system as continuous evaluation will be applied.

To pass the subject, a minimum overall final grade of 5.0 points must be obtained.

Students who have not passed the subject through the single evaluation will have the opportunity to take a final recovery exam that will have the same characteristics as the recovery exam of the continuous evaluation.

The commission of any irregularity in an assessment activity (academic fraud, plagiarism, or improper use of AI, unless such use is explicitly authorized in the course guide) that may lead to a significant alteration of the grade will result in that assessment activity being awarded a grade of ***0 (zero)****. If the course guide establishes that obtaining a minimum grade in that assessment activity is an essential requirement to pass the course, or if multiple irregularities occur in the assessment activities of the same course, the* ***final grade for the course will be 0 (zero)****. Furthermore, independently of these academic consequences, disciplinary proceedings may be initiated against any student who commits any of these irregularities.*

Bibliography

1. An Introduction to Spectroscopy for Biochemists. S.B. Brown, 1980. Academic Press.

2. Principles of Fluorescence Spectroscopy. J.R. Lakowicz, 1983. Plenum Press.

3. Biological Spectroscopy. I.D. Campbell i R.D. Dwek, 1984. Benjamin-Cummings.

4. NMR of Proteins and Nucleic Acids. K. Wüthrich, 1986. Wiley.

5. NMR in Medicine and Biology. Structure Determination, Tomography, in vivo Spectroscopy. K.H. Hausser i H.R. Kalbitzer, 1989. Springer-Verlag.

6. Espectroscopía *in vivo* por Resonancia Magnética Nuclear. J.M. García Segura, 1991. Eudema Universidad.

7. Fluorescence Spectroscopy. New Methods and Applications. O.S. Wolfbeis, 1993. Springer Verlag.

8. Biomolecular NMR Spectroscopy. J.N.S. Evans, 1995. Oxford University Press.

9. NMR and its Applications to Living Systems, 2nd Edition. D.G. Gadian, 1995. Oxford University Press.

10. Infrared Spectroscopy of Biomolecules. H.H. Mantsch i D. Chapman, 1996, Wiley-Liss.

11. Técnicas Instrumentales de Análisis en Bioquímica. J-M. García Segura y col., 1999, Editorial Síntesis, Madrid

12. Fluorescent and Luminiscent Probes for Biological Activity. W.T. Mason, 1999. Academic Press

13. Magnetic Resonance in Chemistry and Medicine. Ray Freeman, 2003. Oxford University Press.

14. Optical Spectroscopy in Chemistry and Life Sciences. Werner Schmidt, 2005.Wiley-VCH.

15. Spectroscopy for the Biological Sciences. Gordon G. Hammes, 2005. Wiley-Interscience.

16. Physical principles and techniques of protein chemistry. Sydney J. Leach Ed., 1973. Academic Press.

17. In vivo NMR Spectroscopy. Principles and Techniques. 2nd Edition. Robin A. de Graff, 2007. Wiley.

18. Fluorescence Applications in Biotechnology and Life Sciences. Ewa M. Goldys Ed., 2009. Wiley-Blackwell.

Scientific articles and web links will be indicated during the course.

Software

Software 'ImageJ' MRI analysis

Software 'Topspin' for RMN analysis

Software 'Quasar' for FTIR and microspectroscopy analysis.

Course groups and languages

The information provided is provisional until November 30. After this date, you will be able to consult the language of each group through this link. To access the information, you will need to enter the course CODE

Type of teaching	Group	Language	Semester	Shift
(TE) Theory	34	Catalan/Spanish	first semester	morning-mixed
(PAUL) Classroom practices	340	Catalan/Spanish	first semester	morning-mixed
(PLAB) Practical laboratories	341	Catalan/Spanish	first semester	morning-mixed