R O M Â N I A
MINISTERUL EDUCAŢIEI ŞI CERCETĂRII
Universitatea din Craiova
FACULTATEA DE ŞTIINŢE/ DEPARTAMENTUL DE CHIMIE
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Subject Description

1. Program information

1.1. Institution	University of Craiova
1.2. Faculty	Science
1.3. Department	Chemistry
1.4. Study field	Chemistry
1.5. Study level	Master
1.6. Type of education	full-time
1.7. Study program	Advanced Chemistry

2. Subject information

2.1. Subject	Advanced Chemical Methods for Cultural Heritage						
2.2. Course coordinator	Lector eng. dr. Elena Badea						
2.3. Application coordinator	Lector eng. dr. Elena Badea						
2.4. Year of study	I	2.5. Semester	2	2.6. Type of evaluation	E	2.7. Subject type	DS/DOB

3. Total estimated tipe (hours/semester)

3.1. Number of hours per week	4	from which: 3.2 course	2	3.3. seminar/lab	2
3.4. Total hours in curriculum	56	from which: 3.5 course	28	3.6. seminar/lab	28

Time allocation – hours/week	
Study using textbooks, course materials, bibliographies, and notes	25
Additional documentation in the library, on specialised electronic platforms, and in the field	20
Preparation of seminars/labs, assignments, reports, portfolios, and essays	15
Tutoring	5
Examinations	4
Other activities............................	
3.7. Total hours of individual study	69
3.8. Total hours per semester	125
3.9. Number of ECTS	5

4. Preconditions (if the case)

4.1. of curriculum	•
4.2. of competences	•

5. Conditions (if the case)

5.1. for course	• Lecture hall equipped with computer, video projection system, and internet connection
5.2. for labs	• Laboratory equipped with the materials, equipment, and reagents necessary to carry out experimental work. Study visit.

6. Course objectives - expected learning outcomes achieved by completing and passing the course

Knowledge	1. Graduates define, understand, explain, and apply advanced knowledge of chemistry to cultural-heritage materials and their alteration. They can describe how inorganic, organic, and polymer chemistry underpin the behaviour and degradation of stone, mortars, metals, glass, ceramics, wood, paper, textiles, paints, plastics, consolidants, and coatings, and can connect this to conservation questions such as stability, compatibility, and treatment performance. 2. Graduates select and use appropriate experimental and theoretical methodologies for heritage problems, including advanced techniques such as TG-DSC, microDSC, solid-state NMR and NMR-MOUSE, alongside IR/Raman, XRF/XRD and chromatographic–MS methods. They understand what each technique measures, its depth and sensitivity, and can evaluate environmental and societal impacts of sampling, solvent and reagent use, and analytical choices in a conservation context. 3. Graduates write structured analytical and scientific reports for heritage objects and materials, integrating multi-method data and clearly explaining methods, results, uncertainty and implications for conservation decisions in line with professional ethics, heritage-sector standards and publication practices. 4. Graduates describe and integrate interdisciplinary knowledge from chemistry, materials science, conservation, art history/archaeology and heritage management into the design and implementation of research projects on cultural heritage, recognising when expertise from other disciplines or large research infrastructures is required.
Skills	1. Graduates apply major concepts from analytical, inorganic, organic and physical chemistry directly to the investigation of heritage materials. They can, for example, relate phase diagrams and corrosion chemistry to metal artefacts, polymer physics to plastics and coatings, and reaction kinetics/thermodynamics to ageing and treatment behaviour monitored by thermal and NMR methods. 2. Graduates evaluate and analyse experimental techniques to design and conduct appropriate experiments on heritage materials, including planning and executing measurements, interpreting specific analytical data, thermograms, chromatograms, spectra. They can test and quantify components and properties (e.g., phases, functional groups, thermal transitions, moisture profiles) and design, coordinate, and run experimental workflows on mock-ups and, where appropriate, on real objects under conservation constraints. 3. Graduates apply critical thinking and the principles of scientific writing to develop, present and defend scientific and technical reports on cultural-heritage case studies. They can critically assess the reliability and limitations of data (including advanced methods), compare alternative interpretations, and justify their conclusions and recommendations to both scientific and non-scientific audiences. 4. Graduates apply interdisciplinary and multi-method approaches to solve complex theoretical and practical problems in heritage science, such as assessing the long-term stability of a consolidant, diagnosing complex composite objects, or evaluating treatment scenarios. They can formulate problems in a way that integrates chemical, physical, mechanical, historical and ethical dimensions.

Responsibility and authonomy	1. Graduates take responsibility for planning and implementing advanced analytical workflows on heritage-related materials, including defining objectives, selecting methods (with justified use of advanced tools and large infrastructures), planning sampling under minimal-damage principles, and managing time, resources and risks. 2. Graduates act autonomously and ethically in laboratory and heritage-site environments, adhering to safety regulations, conservation ethics, legal frameworks and institutional protocols. They can recognise when a proposed analysis or sampling strategy is not acceptable and can propose safer, lower-impact alternatives. 3. Graduates are capable of independently drafting and coordinating small-scale research or diagnostic projects (e.g. MSc thesis or institutional case study), including liaising with conservators, curators and external facilities, preparing documentation for access to specialised instruments or research infrastructures, and ensuring proper data management and reporting. 4. Graduates demonstrate readiness to learn and adopt new methods and infrastructures, critically evaluating emerging techniques (e.g. new mobile NMR devices, improved thermal/ hyphenated methods) and integrating them responsibly into their professional and research practice when appropriate.

7. Table of contents

7.1. COURSE	Mode of operation	Teaching methods	Allocated time (hours)
1.Heritage materials and analytical questions • Overview of materials and deterioration mechanisms • Role of heritage science and types of questions (identification, dating, provenance, technology, state of conservation/stability, previous treatments, treatment performance)	On site (weeks 1 -2)	Lecture, explanation and interactive presentation, heuristic conversation, problem solving	4
2. Vibrational spectroscopy (IR and Raman) • Fundamentals of IR/ATR and Raman; portable equipments, importance of second derivatives for interpreting overlapped signals • Sampling strategies (micro-fragments vs *in situ analysis*) • Typical signatures for pigments, binders, tannins, salts, biomolecules, polymers; strengths and limitations for heritage materials analysis.	On site (weeks 3 - 4)	Lecture, explanation and interactive presentation, heuristic conversation, problem solving	4
3. Elemental and X-ray-based methods (XRF, SEM-EDS, XRD) • Principles of XRF (portable and bench), SEM-EDS, XRD; depth of analysis, detection limits, matrix effects	On site (weeks 5 - 6)	Lecture, explanation and interactive presentation, heuristic conversation, problem solving	4

• Applications to metals, glass, ceramics, mortars, pigments, polymers, and bipolymers.			
5. Principles of thermal analyses • TG and TG-DSC; interpretation of mass-loss and heat-flow curves. • Applications: polymers, biopolymers and consolidants: degradation steps, inorganic/organic residue, effect of ageing, moisture, volatile loss • Principle of micro-calorimetry (high sensitivity, small sample, low heating rates) vs conventional DSC; interpretation of denaturation thermograms. • Applications: thermal denaturation of collagen matrix in skins, leather and parchment.	On site (weeks 7 - 8)	Lecture, explanation and interactive presentation, heuristic conversation, problem solving	4
5. Hyphenated techniques for organic materials • GC-MS and LC-MS fundamentals; sample preparation (extraction, derivatisation); typical targets: binders (oils, proteins), resins, waxes, varnishes, adhesives, consolidants, pollutants. • Py-GC/MS fundamentals; sampling; typical targets: polyphenols/ tannins, resins, oils, proteins, and synthetic polymers	On site (weeks 9 - 10)	Lecture, explanation and interactive presentation, heuristic conversation, problem solving	4
6. Solid-state NMR for cultural heritage • Solid-state NMR (CP/MAS): basics of solid-state NMR: MAS, CP, chemical shift; central nuclei (^{13}C, ^{29}Si, ^{31}P) and what they reveal (network connectivity, cross-linking, functional groups). • Mobile NMR (NMR-MOUSE) and near-surface profiling: principles: stray-field magnets, depth profiling, relaxation times (T_1/T_2) as proxies for mobility and moisture.	On site (weeks 11 - 12)	Lecture, explanation and interactive presentation, heuristic conversation, problem solving	4
7. Multi-method strategies and analytical workflows • Combining non-invasive and	On site (week 13)	Lecture, explanation and interactive presentation, heuristic conversation,	2

micro-destructive techniques • Sampling design and representativeness; • Quality assurance, validation, and uncertainty • Examples of complete workflows from recent heritage case studies.		problem solving	
8. Special topics and risk/ethics • Lecture: constraints of working with unique objects (minimal sampling, reversibility) • Contaminants and health/safety • Ethical aspects and decision-making in sampling and treatment • Communication of analytical results to non-chemists.	On site (week 14)	Lecture, explanation and interactive presentation, heuristic conversation, problem solving	2

References:

1. Analytical Chemistry for Cultural Heritage, Rocco Mazzeo (Editor); Springer Cham, 2017 https://doi.org/10.1007/978-3-319-52804-5
2. Chemical Analysis in Cultural Heritage, Luigia Sabbatini, Inez Dorothé van der Werf (Editors), 2020, De Gruyter
3. Analytical Strategies for Cultural Heritage Materials and Their Degradation, Luigia Sabbatini, Inez Dorothé van der Werf (Editors), Royal Society of Chemistry, 2021.
4. Scientific Methods and Cultural Heritage, Artioli, G. (Editor), Oxford University Press, 2010
5. Conservation Science: Heritage Materials: Edition 2. Paul Garside, Emma Richardson (Editors). Royal Society of Chemistry, 2021
6. Bernhard Blümich, S. Haber-Pohlmeier and W. Zia, Compact NMR, De Gruyter Textbook, 2014. https://doi.org/10.1515/9783110266719
7. Lecture notes, including high-quality video and one concrete case study per week.

7.2. Lab	Mode of operation	Teaching methods	Allocated time (hours)
1. Macroscopic examination and documentation (technical photography, multispectral imaging, condition mapping) 2. Digital optical microscopy on surfaces and cross-sections or to distinguish morphology and stratigraphy.	On site (weeks 1-2)	Experiment, explanation, discussion, debate, and questioning	4
3. ATR-FTIR on reference and mock samples (pigments in	On site (weeks 3 - 4)	Experiment, explanation, discussion, debate, and	4

binders, natural/synthetic polymers, degradation products, microbial metabolites) 4. Micro-Raman or portable Raman, with exercises in spectral interpretation using open libraries		questioning	
5. SEM-EDS session on selected surfaces and cross-sections 6. Portable micro- and macro-XRF mapping on metal or painted mock-ups - Guided data interpretation.	On site (weeks 5 - 6)	Experiment, explanation, discussion, debate, and questioning	4
7. TG-DSC measurements on: untreated vs treated paper or parchment mock-ups; fresh vs artificially aged consolidant or coating. 8. DSC runs on fresh and aged leather mockups; comparison of thermal events detected by DSC and micro-DSC, and information provided.	On site (weeks 7 - 8)	Experiment, explanation, discussion, debate, and questioning	4
9. Simplified workflow using available instruments (e.g. GC-MS of natural resins or oils; HPLC/LC-MS of dyes) 10. Data-driven labs where students interpret real chromatograms and mass spectra from case studies	On site (weeks 9 - 10)	Experiment, explanation, discussion, debate, and questioning	4
11. ^{13}C CP MAS NMR case examples: aged cellulose and lignin; aged and degraded leather 12. NMR-MOUSE case examples: ageing of polymer layers and varnishes via relaxation changes; moisture transport and profiles in inorganic (walls) and organic materials (gild leather)	On site (weeks 11 - 12)	Experiment, explanation, discussion, debate, and questioning	4
13. Mini lab project 1: small groups receive a mock “object file” (images, optical	On site (week 13)	Lab project work	2

microscopy, IR/Raman, XRF, chromatographic data, thermograms) and must reconstruct the workflow, interpret results, and identify remaining uncertainties			
14. Mini lab project 2: design of a sampling and analytical plan for a hypothetical conservation question (e.g. cleaning tests, consolidant evaluation, detection of previous interventions), including risk assessment and documentation templates	Study visit to the conservation laboratory of the Oltenia Museum (week 14)	Lab project work	2
References:			
1. Lab work presentations complemented with conservation-lab and museum case-study clips for practice and context.			

8. Corrrelation of the discipline content with the expectations of representatives of the epistemic community, professional associations, and representative employers in the field related to the program

The course focuses on advanced chemical methods for preserving, restoring, and interpreting cultural heritage, blending chemistry, materials science, and diagnostic techniques. It empowers students with the necessary skills and knowledge to address the complex challenges involved in chemical characterisation and the diagnosis of cultural artefacts. The course is unique in Romania and aligns with similar courses at European universities, meeting the expectations of professional associations and representative employers in the field, i.e., academic research, museum curation, conservation science, and heritage management.

9. Evaluation

Activity	9.1. Evaluation criteria	9.2. Evaluation method	9.3. Contribution to final score
9.4. Course	Concepts, method choice, and data interpretation. Conceptual understanding of techniques. Analytical strategy and method selection Data interpretation and critical thinking.	Written Exam	40%
		Mini-project focusing on the integration of techniques and interpretation.	20%
9.5. Lab	Lab skills and protocol adherence. Data quality and processing. Lab notebooks and short reports. Engagement and teamwork.	Lab project work	40%
9.6. Minimum performance standard			
• Score at least 50% of the exam points • Course & Lab - demonstrate the following:			

(i) Core concepts understanding: Correctly explain the basic principle and main information provided by at least three key technique families without major misconceptions; recognise when a technique is clearly inappropriate

(ii) Ability to choose method and basic analytical strategy: Propose a simple, logically ordered workflow for straightforward cases, even if not optimised; justify at least in general terms why an advanced method (thermal or NMR) might be needed, or why basic tools are sufficient

(iii) Elementary data interpretation

(iv) Show all the following behaviours consistently: safe, reliable lab practice; data acquisition and recording; basic processing and reflection

- Score at least 50% of mini-project points: coherent, realistic project plan; integration of results at a basic level; communication.

The student must meet **all three minimum standards** (exam, lab, mini-project).

Date
22.09.2025

Course coordinator,
Lector.dr. eng. Elena Badea

Date of approval
25.09.2025

Head of Department,
Conf.dr. Nicoleta Cioateră