REPUBLIQUE ALGERIENNE DEMOCRATIQUE ET POPULAIRE

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR ET DE LA RECHERCHE SCIENTIFIQUE

HARMONIZATION

MASTER'S DEGREE PROGRAM OFFER

ACADEMIC/PROFESSIONAL

Institution	Faculty / Institute	Department
Mohamed Seddik Ben Yahia University – Jijel	Exact Sciences and Computer Science	Chemistry

Field: Material Science (SM)

Program: Chemistry

Specialization: Materials Chemistry

Academic Year : 2022-2023

1 – Context and Objectives of the Program

The program comprises three main components:

The first focuses on in-depth knowledge of the physico-chemical and mechanical properties of materials.

The second relates to the development, characterization, and implementation of specific materials for emerging energy technologies, as well as materials with physico-chemical and mechanical functionalities suitable for various application environments under stress.

The third component is oriented toward the industrial-scale use of materials. To this end, the materials studied are intended for applications in diverse fields such as materials chemistry, energy production via new technologies (fuel cells, electrochemical storage, photovoltaics, fusion, catalysis), aeronautics, and the automotive industry.

Through this multidisciplinary training in materials science, the objective is to educate future scientists and researchers who are well-prepared for cutting-edge research environments. They will be capable of designing new functional materials that effectively meet the real needs of technological advancement in various industrial sectors that produce and utilize materials.

A – Admission Requirements

Analytical Chemistry, Analytical and Physical Chemistry, and Materials Chemistry.

B - Objectives of the Program

This Master's program provides scientific and technical training that emphasizes the interdisciplinary and multiscale nature of materials chemistry, with advanced knowledge in the fields of material development, synthesis, characterization, and various treatments (physical, chemical, and thermal).

Foundational knowledge is taught in the first year (M1) and is complemented by elective courses (optional teaching units), site visits, and individual projects. The training is structured around a selection of core modules ("Majors") and advanced elective modules. The M1 year is organized into two semesters, each worth 30 ECTS credits and composed of various teaching units.

The second year (M2), also divided into two semesters, focuses on applying the acquired knowledge to control processes, microstructures, and the final properties of materials using experimental and digital analysis tools. Two specialized tracks are offered, allowing students to guide their future research directions: the first in Electrochemistry, and the second in Materials and Catalysis.

The program also includes instruction on spectroscopic and electrochemical analysis methods to further strengthen scientific and technical competencies. The second semester of M2 is entirely dedicated to an internship called the Final Year Project (FYP), designed to prepare students for professional life and research. It culminates in a supervised project and a defense before an academic jury.

C – Profiles and Career Skills Targeted

The Master's in Materials Chemistry (Master CM) at the University of Jijel is aimed at graduates with an Academic Bachelor's degree in Chemistry, with priority given to those specializing in Materials Chemistry and Analytical Chemistry.

The main goal of the Master's program is to train future professionals and researchers in the field of Electrochemistry and Materials for Catalysis, covering areas such as synthesis, physical and physico-chemical characterization, modeling, properties, and applications.

To produce high-level specialists, the objectives of the Master's program include:

- Acquiring fundamental knowledge in Physical Chemistry and Electrochemistry.
- Deepening knowledge of the latest methods and techniques.
- Expanding into related disciplines.

D – Pathways to Other Specializations

Transfers are possible (after validation of M1-S1 and M1-S2) to other Chemistry options (within the same fields and domains) or to the field of Materials Science (Specialization: Solid-State Physics; Materials Chemistry).

II – Semester Teaching Organization Sheet

(Please present the sheets for all 4 semesters)

3- Semester 3 :

Teaching Unit	VHS	Weekly Hourly Volume				Coeff	Credits	Mode of evaluation	
	14-16 sem	L	T	PW	OA			Continuous Assessment	Exam
Core Units	**202h30**	**13h30**				**11**	**18**		
UEC1(O/P)									
Structural Crystallography	45h00	01h30	01h30			2	4	33 %	67 %
Crystal Growth	67h30	03h00	01h30			4	6	33 %	67 %
UEC2(O/P)									
Crystal Field Theory	45h00	01h30	01h30			3	4	33 %	67 %
Semiconductors and Applications	45h00	01h30	01h30			2	4	33 %	67 %
Methodology Units	**105h00**	**07h00**				**4**	**9**		
UEM1(O/P)									
Molecular Modeling	45h00	01h30	01h30			2	3	50 %	50 %
UEM2(O/P)									
Practical Work V	30h00			02h00		1	3	50 %	50 %
Practical Work VI	30h00			02h00		1	3	50 %	50 %
Discovery Unit	**22h30**	**01h30**				**1**	**1**		
UED1(O/P)									
Ethics and Professional Conduct	22h30	01h30				1	1		100 %
Transversal Unit	**45h00**	**3h00**				**2**	**2**		
UET1(O/P)									
Introduction to Research	45h00	01h30	01h30			2	2		100 %
Total Semester 3	**375h00**	**12h00**	**09h00**	**04h00**		**18**	**30**		

4- Semester 4 :

Field: Material Science

Program: Chemistry

Specialization: Materials Chemistry

Internship in a company, concluded with a thesis and an oral defense.

	VHS	Coeff	Credits
Personal Project (Final Year Thesis + Oral Defense before a Jury)	375h00	9	**18**
Literature Review	375h00	6	**9**
Seminars (defined as Discovery Units – UED)	9h00	3	**3**
Total Semester 4	**375h00**	**18**	**30**

5- Overall Summary of the Program: (Indicate the total hourly volume separated into Lectures (L), Tutorials (T), and Practical Work (PW) over the 4 semesters of teaching, for each type of Teaching Unit – UE)

UE / VH	UEC	UEM	UED	UET	Total
L	360h00	67h30	67h30	90h00	585h00
T	270h30	67h30	00	00	338h00
PW	00	180h00	00	00	180h00
Personal Project	200h00				200
Internship in a company	140h00				140
Total	970h30	315h00	67h30	90h00	1103h00
Credits	72	36	7	5	**120**
% of credits for each Teaching Unit (UE)	60 %	30 %	5,83 %	4,17 %	100 %

III - Detailed Program by Subject

(1 detailed sheet per subject)

Master's Title: Materials Chemistry
Semester: 3
Course Unit Title: UEF 1
Course Title: Structural Crystallography
Credits: 4
Coefficient: 2

Course Objectives

To provide a foundation in crystallography and the study of the structure of crystalline solids.

Recommended Prerequisite Knowledge

Basic knowledge of geometric and structural crystallography.

Course Content

Chapter I: Chemical Bonding in Crystals

Introduction
Attractive forces: Strong bonds (covalent, ionic, metallic), Weak bonds (Van der Waals, hydrogen, charge transfer forces), Intermediate bonds (ion-dipole interaction)
Repulsive forces (electrostatic repulsion, Born repulsion forces)
Coordination: definition, coordination number in covalent and ionic bonding, coordination polyhedra
Types of crystals based on bonding and chemical, steric, and electronic factors

Chapter II: Crystalline Structures (Perfect Crystals)

Metals and their alloys (physical and chemical properties, atomic arrangement, packing, structures)

Ionic structures: general characteristics, binary compounds (types AB, AB_2, A_2B – structure descriptions and geometric stability conditions), ternary compounds (types ABO_3, AB_2O_4 – structure descriptions and stability conditions), Pauling's rules, lattice energy

Covalent structures: type A (diamond), AB, AB_2

Intermediate structures (graphite)

Molecular structures: type A (noble gases), A_2 (N_2, H_2), AB (CO), AB_2 (H_2O, CO_2), An (P_4, S_8)

Chapter III: Imperfections (Real Crystals) and Reactivity (Diffusion and Convection)

Physical defects: point, line, planar, and bulk defects

Chemical defects: non-stoichiometry

Chapter IV: Physical Properties of Crystals

Optical, electrical, and magnetic properties

Assessment Method: Continuous assessment and final exam

References

- Cristallographie géométrique et radiocristallographie, *Jean-Jacques Rousseau et Alain Gibaud.*
- Crystal Structure Analysis, 3th édition, *Jenny* Pickworth Glusker *and* Kenneth N. Trueblood

Master's Program Title: Materials Chemistry
Semester: 3
Course Unit Title: UEF 1
Course Title: Crystal Growth
Credits: 6
Coefficient: 4

Course Objectives

- Understand the definition of crystal growth and the different mechanisms involved;
- Learn how to control crystal growth to obtain a specific habit (external shape);
- Determine the growth rate and mechanisms.

Recommended Prerequisites

Basic knowledge of solid-state chemistry, geometric and structural crystallography.

Course Content

Chapter I: Elements of Crystallography

✓ Review: Crystalline vs. amorphous states, crystal symmetry (symmetry elements, crystal systems, etc.), lattice planes and rows, crystal structures, crystal defects, Bragg's law.

Chapter II: Crystallization

✓ Generalities on crystallization, recrystallization, supersaturation, supercooling, precipitation, the relationship between precipitation and crystallization, crystal quality.

✓ Crystallization modes: Phase transition (diffusion-based and diffusionless transformations), crystallization from solution.

✓ Crystallization modes: Phase transitions (liquid → solid; gas → solid; amorphous solid → crystalline solid), crystallization from a solution (by cooling, evaporation, salting out, etc.).

✓ **Nucleation**: Definition, types (homogeneous/primary and heterogeneous/secondary), nucleation rate, mechanisms (primary and secondary), conditions for the formation and stability of spherical nuclei.

✓ **Crystal Growth**: Definition, critical rate, thermodynamic and energetic aspects.

✓ Thermodynamic and energetic aspects (mother phase transition and internal energy of the phase system).

✓ Crystal habit and faces.

✓ Dynamic aspects (oriented aggregation, dendritic instabilities).

Chapter III: Theories of Crystal Growth

- ✓ **Structural theories**: Growth as a capillary phenomenon (Curie's law), face growth rate as a form-determining factor, spherical crystal model, face dissolution rate, Gibbs thermodynamic approach, Wulff theorem, Hartmann and Perdok theory, structure-related growth (Haüy's multiple layer law).
- ✓ **Kinetic theories**: Kossel-Stranski-Volmer theory, Volmer's growth mechanism, Gilmer and Bennema theory (rough vs. smooth interface theory), Frank's theory.
- ✓ Growth mechanisms and rate (growth rate expressions, general description and main stages of the growth mechanism).

Chapter IV: Factors Influencing Crystal Growth

- ✓ Solvent, additives, and impurities
- ✓ Crystal size, temperature, transport phenomena (diffusion, convection)
- ✓ Surface: growth by 2D surface nucleation (polynuclear and spread nucleation mechanisms), dislocation.

Chapter V: Main Methods and Techniques of Crystal Growth

- ✓ **From the melt**: Bridgman–Stockbarger method, Czochralski process, Kyropoulos method, Stepanov method, EFG method (Edge-defined film-fed growth), Verneuil process, float-zone technique, arc melting growth.
- ✓ **From solvents**: By cooling the solution, solvent evaporation, salting out, hydrothermal solution growth.
- ✓ **Growth by physical transport or sublimation**
- ✓ **Growth by chemical transport**: CVT (chemical vapor transport) or CVD (chemical vapor deposition).
- ✓ **Epitaxy**: Molecular beam epitaxy, liquid-phase, vapor-phase epitaxy. Sintering, polymerization, sedimentation, simple melting and rapid cooling (glass formation).

Assessment Method: Continuous assessment and final exam.

References

- Physique de la croissance cristalline, Jacques Villain et Alberto Pimpinelli (1999).
- Du Verre Au Cristal, Nucléation, croissance et démixtion, de la recherche aux applications, par : Daniel R. Neuville, Laurent Cormier, Daniel Caurant et Lionel Montagne.

Master's Program Title: Materials Chemistry
Semester: 3
Course Unit Title: UEF 2
Course Title: Crystal Field Theory
Credits: 4
Coefficient: 3

Course Objectives

- Understand the different geometries of transition metal complexes (especially coordination numbers 4 and 6).
- Grasp the factors favoring complex formation (chelate effects, influence of the metal, etc.).

Recommended Prerequisites

Theoretical chemistry.

Course Content

Chapter I: Generalities on Coordination Compounds

Definitions and general properties of transition elements.

Complexes and ligands, nomenclature, geometry, coordination number, and isomerism.

Chapter II: Stability and Reactivity of Complexes

Formation and stability of complexes.

Reactivity of complexes (substitution, redox reactions, etc.).

Reactivity from a theoretical point of view.

Chapter III: Crystal Field Theory

Valence Bond Theory (Pauling).

Crystal Field Theory: Shapes of d atomic orbitals and removal of degeneracy.

Influence of environmental symmetry and calculation of the Crystal Field Stabilization Energy (CFSE).

Application: Stability of spinels.

Factors affecting the crystal field energy value (nature of the central ion, oxidation state, symmetry, etc.).

Jahn–Teller effect and square planar crystal field.

Electron counting and the 18-electron rule.

Molecular orbital model in complexes.

Chapter IV: Properties of Coordination Compounds

Optical properties and absorption of coordination compounds.

Types of transitions and spectroscopic terms.

Transitions in complexes.

Magnetic properties of transition elements.

Magnetic measurements and Curie's Law.

Assessment Method: Continuous assessment and final exam.

References :

- Yves Jean, Les orbitales moléculaires dans les complexes cours et exercices corrigés, les éditions de l'école polytechnique, Paris 2006.
- Wulfsbrg G., Chimie inorganique : Théorie et application, Edition DUNOD, Paris 2002.
- S. F. A. Kettle, Physico-chimie inorganique, une approche basée sur la chimie de coordination, traduction française, De Boeck Université, Paris 1999.
- Roland Lissilour, Chimie Théorique : Application à la spectroscopie, Edition DUNOD, Paris 2001.
- D.F. Shriver, P.W. Atkins, Chimie inorganique, Traduction française, De Boeck Université, Paris, 2001.
- Huheey J. E., Keiter E.A., Keiter R. L., Inorganic Chemistry, Principles of Structure and Reactivity, 4th Ed., Harper Collins College Publishers, 1993, New York, USA.

Master's Program Title: Materials Chemistry
Semester: 3
Course Unit Title: UEF 2
Course Title: Semiconductors and Applications
Credits: 4
Coefficient: 2

Course Objectives

This course enables students to acquire general knowledge of inorganic materials and in-depth understanding of semiconductor materials and their physicochemical properties, with a particular focus on environmental applications.

Recommended Prerequisites

Theoretical chemistry

Course Content

Chapter I: General Concepts and History of Materials

- Semiconductor materials
- Conductive materials
- Insulating materials

Chapter II: Conduction Mechanisms in Semiconductor Materials

- Intrinsic semiconductors
- Extrinsic semiconductors (n-type and p-type)
- Fermi level
- Semiconductor coupling
- Semiconductor doping

Chapter III: Crystal Defects

- Point defects
- Grain boundaries and dislocations
- Surface states

Chapter IV: Optical Study of Semiconductors

- Band gap concept (energy bands)
- Direct band gap
- Indirect band gap

Chapter V: Contact Phenomena in Semiconductor Materials

- Conventional energy model of the semiconductor/electrolyte interface in the dark
- Description of the electrical double layer on the electrolyte side
- Description of the electrical double layer on the semiconductor side

Chapter VI: Applications

- Photoelectrochemical behavior of semiconductors under light
- Advanced oxidation processes: definitions, principles, radical reactivity, indirect photodegradation ("photolysis")
- Photocatalysis: photocatalytic reactions, optimization of reaction parameters, degradation mechanisms
- Application to the photodegradation of environmental pollutants

Assessment Method

Continuous assessment and final exam

References

- Mercier, Jean P., Gérald Zambelli, and Wilfried Kurz. Introduction à la science des matériaux. Vol. 1. PPUR presses polytechniques, 1999.
- Lévy, Francis. Physique et technologie des semiconducteurs. Vol. 18. PPUR presses polytechniques, 1995.
- Guillien, R. (1978). Les semiconducteurs et leurs applications. FeniXX.
- Delaire, Jacques, et al. Photophysique et photochimie : Des fondements aux applications. EDP sciences, 2017.
- Dauvin, Jean-Philippe. *Les semi-conducteurs*. FeniXX, 1990.

Master’s Program Title: Materials Chemistry
Semester: 3
Course Unit Title: UEM 1
Course Title: Molecular Modeling
Credits: 4
Coefficient: 3

Course Objectives

The aim of this course is to introduce students to the concept of modeling, with applications in molecular modeling, and to provide an introduction to molecular mechanics calculations.

Recommended Prerequisites

Theoretical chemistry and crystal field theory

Course Content

Chapter I: Introduction to Modern Quantum Techniques for Molecular Modeling

Chapter II: Quantum Methods

- Hückel method
- Self-consistent field methods (Ab initio methods, Semi-empirical methods)
- Density Functional Theory (DFT)

Chapter III: Molecular Mechanics

Chapter IV: Molecular Dynamics

Chapter V: Molecular Modeling Software

- Structure building, visualization, and manipulation
- Calculations
- Structure saving
- Study of molecular properties

Assessment Method

- Continuous assessment and final exam
- Continuous assessment: 50%
- Final exam: 50%

References

- J. Debord, Introduction à la modélisation moléculaire. 2004, 37-41.
- H. Dugas, Principes de base en modélisation moléculaire, Aspects théoriques et pratiques, Chapitre 3 introduction aux méthodes de minimisation d'énergie, quatrième édition, Librairie de l'Université de Montréal, 1996.
- Chavent et al. (2016) "Molecular dynamics simulations of membrane proteins and their interactions: from nanoscale to mesoscale" Curr. Opin. Struct. Biol. 40, 8 - 16.
- E. Schrudinger, Ann.Phys. Leipzig, 1926, 79, pp. 361, 489, 734

Master's Program Title: Materials Chemistry
Semester: 3
Course Unit Title: UEM 2
Course Title: Practical Work VI
Credits: 3
Coefficient: 1

Course Objectives

This course aims to provide students with the experimental foundations in chemistry necessary for analyzing and solving an environmental problem through photocatalytic reactions using solar energy as a renewable source.

Recommended Prerequisites

Homogeneous and heterogeneous catalysis

Course Content

Part I

- **Lab 1**: Synthesis of a semiconductor for a photocatalytic application
- **Lab 2**: Study of the photocatalytic reduction of hexavalent chromium using a pre-characterized semiconductor
- **Lab 3**: Photocatalytic degradation of an azo dye under visible light

Part II: Solid Analysis

- **Lab 1**: Construction of compact stacking structures and identification of interstitial sites (tetrahedral and octahedral sites)
- **Lab 2**: Study of some universal crystalline structures using exploded models

Assessment Method

Continuous assessment and final exam

References

- Sarantopoulos, C. (2007). Photocatalyseurs à base de TiO2 préparés par infiltration chimique en phase vapeur (CVI) sur supports microfibreux.
- V. K. Pecharsky & P. Y. Zavalij, Fundamentals of powder diffraction and structural characterization of materials, Springer (2003)
- W. Clegg, A. J. Black, R. O. Gould & P. Main. Crystal structure analysis: principles and practice, IUCr & Oxford science publication (2006).

Master's Program Title: Materials Chemistry
Semester: 3
Course Unit Title: UEM 2
Course Title: Practical Work VII
Credits: 3
Coefficient: 1

Course Objectives

The student will become familiar with the main quantum chemistry methods used to represent molecular and solid systems, including their applications and limitations. They will learn how to select an appropriate method for addressing a given problem and how to interpret simulation results to understand common physicochemical phenomena.

Recommended Prerequisites

Quantum Chemistry and Computer Science

Course Content

Part I

- *Ab initio* and semi-empirical methods, energy minimization, global and local minima, electrostatic potential, molecular orbitals, charges
- Intermolecular forces, molecular rotation and vibration
- Conformational sampling, simulation of molecular motions
- Molecular dynamics and Monte Carlo simulations
- Modeling of macromolecular systems
- Software: Gaussian, HyperChem, Spartan

Part II: Structural Crystallography

- **Lab 1**: Study of cobalt(II) complexation
- **Lab 2**: Determination of nickel stoichiometry through EDTA complexation
- **Lab 3**: Study of the spectrochemical series of copper(II)

Assessment Method : Final exam

References

J. Debord. : Introduction à la modélisation moléculaire. (2004).
G. SEGAL, "La modélisation moléculaire - Les logiciels : tendances et évolution", Le Technoscope de Biofutur, n° 34, février 1990.

Master’s Program Title: Materials Chemistry
Semester: 3
Course Unit Title: UET 3
Course Title: Ethics and Professional Conduct
Credits: 2
Coefficient: 1

Course Content

Introduction: Definition of ethics and professional conduct

Chapter 1: Charter of University Ethics and Professional Conduct

1. Integrity and honesty
2. Academic freedom
3. Responsibility and competence
4. Rights and obligations of the teacher-researcher
5. Rights and duties of higher education students
6. Rights and obligations of administrative and technical staff in higher education

Chapter 2: The Global Chemists Code of Ethics (GCCE)

- **Introduction**

1. Codes of good conduct
2. GCCE context and development
3. Preparation of The Hague Ethical Guidelines
4. Key elements of The Hague Ethical Guidelines:
    - Core Element
    - Sustainability
    - Education
    - Awareness and Engagement
    - Ethics
    - Safety and Security
    - Responsibility
    - Oversight
    - Information Exchange
5. Who is the GCCE for?
6. GCCE Sections:
    - Environment (Environment, البيئة)
    - Research (Research, البحث)
    - Scientific Writing and Publishing (الكتابة العلمية والنشر)
    - Safety (السلامة)
    - Security (الأمن)

Assessment Method

Final Exam: 100%

References :

- Confraternité et concurrence à la recherche d'une déontologie inspirée, (Bellis, Jean-François, 2009).
- Ethique, Déontologie et Gestion de L'Entreprise, (Bruslerie, Hurbert, 2009).
- Charte de l'éthique et de la déontologie universitaire (2010) :
https://www.mesrs.dz/conseil-d-ethique1
https://www.opcw.org/hague-ethical-guidelines
https://www.acs.org/content/acs/en/global/international/science-and-human-rights.html

Master's Program Title: Materials Chemistry
Semester: 3
Course Unit Title: UED 3
Course Title: Ethics and Professional Conduct
Credits: 2
Coefficient: 1

Course Objectives

To conduct scientific research and develop a comprehensive bibliographic synthesis.

Recommended Prerequisites

Basic knowledge of office tools and internet use. Good proficiency in both French and English.

Course Content

Chapter I: Research Methodology

- Research methods and various sources of scientific documentation, including computerized databases.

Chapter II: Bibliographic Analysis

- Conducting an exhaustive bibliographic search on the state of the art related to a proposed topic.
- Analyzing and synthesizing bibliographic data.

Chapter III: Bibliographic Synthesis

- Writing a scientific document.
- Preparing an oral presentation in English or French.

Assessment Method

Continuous assessment (assignments, quizzes) and a final exam.

References

- Site internet de la documentation en ligne du ministère de l'enseignement supérieure et de la recherche scientifique : www.sndl.cerist.dz.
- Bases de données disponible au niveau du centre de calculs