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)

1- Semester 1 :

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**				**10**	**18**		
UEC1(O/P)									
Spectroscopic Methods	45h00	01h30	01h30			02	04	33 %	67 %
Electrochemistry	67h30	03h00	01h30			04	06	33 %	67 %
UEC2(O/P)									
Chemical Catalysis	45h00	01h30	01h30			02	04	33 %	67 %
Geometrical Crystallography	45h00	01h30	01h30			02	04	33 %	67 %
Methodology Units	**75h00**	**07h00**				**5**	**9**		
UEM1(O/P)									
Material Development Methods	45h00	01h30	01h30			02	04	50 %	50 %
Practical Work I	30h00			02h00		02	03	50 %	50 %
UEM2(O/P)									
Practical Work II	30h00			02h00		01	02	50 %	50 %
Discovery Unit	**22h30**	**01h30**				**1**	**1**		
UED1(O/P)									
Environmental Protection I	22h30	01h30				01	01		100 %
Transversal Units	**45h00**	**03h00**				**2**	**2**		
UET1(O/P)									
English	22h30	01h30				01	01		100 %
Computer Science	22h30	01h30				01	01		100 %
Total Semester 1	**375h00**	**13h30**	**07h30**	**04h00**		**18**	**30**		

2- Semester 2 :

Teaching Unit	VHS	Weekly Hourly Volume				Coeff	Credits	Mode of evaluation	
	14-16 sem	L	T	PW	OA			Continuous Assessment	Exam
Core Units	**225h00**	**15h00**				**10**	**18**		
UEC1(O/P)									
Electrochemical Analysis Methods	67h30	03h00	01h30			3	5	33 %	67 %
Physical and Mechanical Properties of Materials	45h00	01h30	01h30			2	4	33 %	67 %
UEC2(O/P)									
Solid State Analysis	67h30	03h00	01h30			3	5	33 %	67 %
Advanced Chemical Kinetics	45h00	01h30	01h30			2	4	33 %	67 %
Methodology Units	**105h00**	**07h00**				**6**	**9**		
UEM1(O/P)									
Thermal Analysis Method	45h00	01h30	01h30			2	3	33 %	67 %
Practical Work III	30h00			02h00		2	3	50 %	50 %
Practical Work IV	30h00			02h00		2	3	50 %	50 %
Discovery Unit	**22h30**	**01h30**				**1**	**2**		
UED1(O/P)									
Materials for Energy Storage	22h30	01h30				1	2		100 %
Transversal Unit	**22h30**	**01h30**				**1**	**1**		
UET1(O/P)									
Environmental Protection I	22h30	01h30				1	1		100 %
Total Semester 2	**375h00**	**13h30**	**07h30**	**04h00**		**18**	**30**		

Master's Title: Materials Chemistry
Semester: 1
Teaching Unit Title: UEC1
Subject Title: Spectroscopic Methods
Credits: 4
Coefficients: 2

Teaching Objectives

Inorganic Spectroscopy encompasses all techniques that allow the analysis of chemical elements present in a sample, whether in mineral or molecular form. This course aims to introduce modern microstructural analysis tools for inorganic materials.

Recommended Prerequisite Knowledge

Basic concepts of general physics, analytical chemistry, and crystallography.

Course Content

Chapter I: *X-Ray Fluorescence (XRF)*

- *Definition*
- *Principle of X-Ray Fluorescence*
- *Instrumentation and Sample Preparation*
- *Applications of X-Ray Fluorescence*
- *Energy Dispersive X-Ray Fluorescence (EDXRF)*
- *Wavelength Dispersive X-Ray Fluorescence (WDXRF)*

Chapter II: *Scanning Electron Microscopy (SEM)*

- *Definition*
- *Principle of Scanning Electron Microscopy*
- *Instrumentation and Sample Preparation*
- *Applications of Scanning Electron Microscopy*

Chapter III: *Energy Dispersive X-Ray Microanalysis (EDX)*

- *Definition*
- *Principle of Energy Dispersive X-Ray Microanalysis*
- *Instrumentation and Sample Preparation*
- *Applications of Energy Dispersive X-Ray Microanalysis*

Chapter IV: *Transmission Electron Microscopy (TEM)*

Chapter V: *Atomic Force Microscopy (AFM)*

Chapter VI: *X-ray Photoelectron Spectroscopy (XPS)*

Chapter VII: *Secondary Ion Mass Spectrometry (SIMS)*

Evaluation Method: *Continuous assessment, exam*

References

Spectroscopy Solid-State: An Introduction. Editeur: Springer

Méthodes usuelles de caractérisation des surfaces, D. David, R. Caplain, Eyrolles (1988)

Micro caractérisation des solides, M. Ammou, CRAM-LPSES-CNRS

Chimie inorganique, Catherine E. HOUSECROFT

Chimie inorganique, D.F. SHRIVER

Master's Title: Materials Chemistry
Semester: 1
Teaching Unit Title: UEC1
Subject Title: Electrochemistry
Credits: 6
Coefficients: 4

Teaching Objectives

This course aims to introduce the importance of electrochemical phenomena that occur in electrochemical cells.

Recommended Prerequisite Knowledge

Redox reactions, electrochemistry of solutions.

Course Content

Chapter I: Kinetics of Phenomena at Electrodes

Polarization phenomena, charge transfer overvoltage, diffusion overvoltage, crystallization overvoltage, total overvoltage, polarization resistance.

Chapter II: Electrodeposition of Metals

Chapter III: Electrochemical Dissolution and Passivation of Metals

Chapter IV: Corrosion Phenomena

- Definition
- Electrochemical elements and different forms of corrosion: Ellingham diagram
- Dry corrosion, aqueous corrosion (Nernst equation, Pourbaix diagram, electrochemical kinetics, Butler-Volmer equation, Tafel lines, corrosion potential)
- Uniform corrosion: atmospheric corrosion, uniform aqueous corrosion, case of passivatable materials
- Localized corrosion: galvanic, pitting, crevice effect, intergranular, erosion corrosion, cavitation corrosion
- High-temperature corrosion
- Protection against corrosion: Physical protection – Passivation, protection by coatings, inhibitors, electrochemical protection
- Industrial impacts and issues related to corrosion

Chapter V: Electrochemistry of Solids

Evaluation Method: Continuous assessment, exam

References

Physical and Analytical Electrochemistry. Author: Hubert H. Girault.

Electrochemistry: From Concepts to Applications. Course, practical work, and solved problems. Author: Fabien Miomandre

Chemical and Electrochemical Thermodynamics. Author: Robert Roux.

Electrochemistry: From Concepts to Applications. Course, practical work, and solved problems. Author: Fabien Miomandre

Thermodynamics & Electrochemical Kinetics: From Models to Experimental Practices. Author: Christophe Aronica

Corrosion and Surface Chemistry of Metals, D. Landolt, Treatise on Materials, Volume 12, Presses Polytechniques et Universitaires Romandes

Master's Title: Materials Chemistry
Semester: 1
Teaching Unit Title: UEF 2
Subject Title: Chemical Catalysis
Credits: 4
Coefficients: 2

Teaching Objectives

The course aims to understand the type of process and relate it directly to the surface of the catalyst.

Recommended Prerequisite Knowledge

Solid chemistry, surface chemistry.

Course Content

Chapter I: Homogeneous Catalysis

1- Acid-base catalysis
2- Redox catalysis
3- Coordination catalysis

Chapter II : Heterogeneous Catalysis

- Thermodynamics of adsorption – Adsorption heat
- Kinetics of adsorption
- Basics of chemical kinetics in heterogeneous catalysis
- Langmuir-Hinshelwood model

Chapter III : Catalyst Preparation

1. **Quality of a catalyst:**
   - Activity
   - Selectivity
   - Stability
   - Cost
2. **Active surface**
3. **Supported catalysts**
4. **Introduction of the active phase:**

- Impregnation
- Coprecipitation
- Mixing

5. **Shaping of industrial catalysts:**

- From solids
- From solutions

6. **Catalyst activation**
7. **Deactivation**

Chapter IV: Heterogeneous Catalysis in Industrial Processes

- Heterogeneous catalysis in the refining industry for fuel production
- Heterogeneous catalysis in petrochemical and chemical industries
- In mineral chemistry (production of ammonia, nitric acid, and sulfuric acid)
- Automotive pollution control
- Production and conversion of hydrogen and synthesis gases

Evaluation Method: Exam, continuous assessment

References

- Catalyse hétérogène dans les procédés industriels, Auteur(s) : Denis UZIO, techniques-ingenieur 2018
- Introduction to the principles of heterogeneous catalysis, J. M. Thomas, W. J. Thomas, © VCH 1997.
- Heterogeneous Catalysis, Fundamentals and Applications, Julian R.H. Ross, © Elsevier 2012.
- Cinétique et catalyse (2e édition), G. Scacchi, © Lavoisier 2011.
- Cinétique chimique et catalyse hétérogène, B. Gilot, © Ellipes 2004.

Master's Title: Materials Chemistry
Semester: 1
Teaching Unit Title: UEF2
Subject Title: Geometrical Crystallography
Credits: 4
Coefficients: 2

Teaching Objectives

This course aims to review the basics of geometrical crystallography and to describe and study the structure of crystallized solids.

Recommended Prerequisite Knowledge

Basic knowledge of geometrical crystallography.

Course Content

Chapter I: Reminders and Crystallographic Notions

1. Introduction to the states of matter
2. Real space or direct lattice:
    - Definition
    - The crystal, motif, point lattice, node, lattice row, period, lattice plane Miller indices, interplanar distance
    - Unit cell and its multiplicity
    - Crystal systems, Bravais lattices
    - Applications: Exclusion of mode C for the square unit cell and the cubic unit cell

3- Reciprocal space or reciprocal lattice:
- Definition
- Properties of the reciprocal lattice
- Expression of interplanar distances in terms of reciprocal parameter
- Relations between direct and reciprocal quantities

Chapter II: Symmetry of Finite Figures

- Symmetry operations (rotation, reflection, inversion, rotational inversion, rotational reflection, translation), symmetry operators
- Equivalent positions
- Coexistence of symmetry elements (symmetry groups; theorems)
- Point groups (one-dimensional, two-dimensional, three-dimensional)

Chapter III: Symmetry in Lattices

1- Orientation symmetry

- Symmetry elements
- Representation of point groups
- Stereographic projection

2- Positional symmetry:

- Translational symmetry elements
- Translation groups
- Representation of space groups, cotangent projection
- Use of International Tables for Crystallography

Evaluation Method: Continuous assessment, exam

References

Geometrical Crystallography and Radiocrystallography, Jean-Jacques Rousseau and Alain Gibaud

Master's Title: Materials Chemistry
Semester: 1
Teaching Unit Title: UEM1
Subject Title: Methods for Material Preparation
Credits: 4
Coefficients: 2

Teaching Objectives

- ➢ Describe the different aspects of manufacturing mineral or organo-mineral hybrid systems.
- ➢ Present the physicochemical properties of these systems and their applications in ceramics, thin films, and nanomaterials.

Recommended Prerequisite Knowledge

Thermodynamics of phase equilibrium, mass transfer, heat transfer, and fluid mechanics.

Course Content

Chapter I: Definition and Classification of Materials

- Definition of materials
- Classification by origin
- Classification by atomic structure
- Classification by design

Chapter II: Solid-State Reactions: Ceramic Method

- Reactants
- Mixing/Grinding
- Thermal treatment
- Sintering: Determination of sintering temperature
- Applications of the ceramic method
- Disadvantages of the ceramic method

Chapter III: Reactions in Solution: "Soft Chemistry" Methods

- Co-precipitation of hydroxides

- Sol-gel method: Mineral growth of molecules to materials, Hybrid materials, Example applications of hybrid materials
- Decomposition of mixed complexes: Pechini method

Chapter IV: Hydrothermal, Solvothermal, and Combustion Methods

- Definition
- Experimental setup
- Advantages of the methods
- Disadvantages of the methods

Chapter V: Colloidal Chemistry

- Importance of research on nanoparticles
- Principles of colloidal nanoparticle synthesis
- Physical properties of nanoparticles
- Examples of applications

Chapter VI: Preparation of Thin Films

- Chemical methods: Chemical Vapor Deposition (CVD)
- Physical methods: Physical Vapor Deposition (PVD)

Chapter VII: Nanomaterials

- Importance of research on nanoparticles
- Principles of colloidal nanoparticle synthesis
- Examples of applications

Evaluation Method: Continuous assessment, exam.

References

- Matériaux - de l'élaboration à l'utilisation des matériaux - caractéristiques, obtention, emplois, Éric Felder - Collection Technosup, Éditeur(s) Ellipses 2020.
- ceramiques et verres, Principes et techniques d'élaboration, Jean-Marie Haussonne, James L. Barton, Paul Bowen et Claude Paul Carry, Traité des matériaux, Vol. 16.
- cristallographie geometrique et radiocristallographie, *Jean-Jacques Rousseau et Alain Gibaud.*
- introduction a la cristallochimie, solide cristallise et empilements compact, Didier Rioux.

Master's Title: Materials Chemistry
Semester: 1
Teaching Unit Title: UEM1
Subject Title: Practical Work I
Credits: 3
Coefficients: 2

Teaching Objectives

To introduce students to different synthesis methods from soft chemistry and solid-state chemistry for material preparation.

Recommended Prerequisite Knowledge

Course on Methods for Material Preparation.

Course Content
Part I: Practical Work – Material Preparation

1. Solid-State Route

   Preparation of materials using high-temperature solid reactions.

2. Soft Chemistry Methods:

   - Co-precipitation
   - Sol-gel process
   - Citrate method
   - Nitrate method

3. Dry Methods (Conventional)

   Introduction to classical high-temperature synthesis techniques.

Part II: Practical Work – Geometric Crystallography

TP 1: Construction of Various Types of Crystal Lattices

Objective: Develop the student's spatial visualization skills.

Materials Used: Balls and rods.

Activities:

- Construction of 1D (straight line and zigzag) lattices with parameter identification.

- Construction of 2D simple and multiple lattices.
- Construction of 3D simple and multiple lattices according to suitable crystal systems.
- Identification of selected reticular planes (hkl) and reticular directions [uvw].

TP 2: Application of Symmetry Elements to a Crystal Unit Cell

Objective: Improve spatial understanding and grasp symmetry element applications and their consistency in crystal structures.

Evaluation Method : Lab reports and final exam.

References

- *Chimie des solides*, Jean-Francis Marucco.
- *Exercices de chimie des solides*, Jean-Francis Marucco.

Master's Title: Materials Chemistry
Semester: 1
Teaching Unit Title: UEM1
Subject Title: Practical Work II
Credits: 2
Coefficients: 1

Teaching Objectives

This course enables students to link fundamental concepts in electrochemistry with practical laboratory applications.

Recommended Prerequisite Knowledge

Electrochemistry

Course Content

Part I – Electrochemistry and Corrosion Studies

- Plotting of Potential–pH Diagrams (Pourbaix Diagrams) for Iron
- Evans Method Experiment (Electrochemical technique for corrosion rate analysis)
- Electrochemical Corrosion and Corrosion Protection
- Evaluation of corrosion behavior in different media
- Application of protective measures (inhibitors, coatings, cathodic protection)

Part II – Applied Chemistry Investigations

TP-1: Study of Liquid Phase Adsorption

- Adsorption isotherms and kinetics
- Application to pollutant removal or material interfaces

TP-2: Study of a Surfactant

- Determination of critical micelle concentration (CMC)
- Surface tension measurements

TP-3: Study of a Homogeneous Catalysis Reaction

- Reaction kinetics and catalytic efficiency
- Example of an acid-base or redox homogeneous catalytic system

Evaluation Method

Continuous assessment and final exam (written or oral depending on institution policy).

References

- Chimie des solides, Jean-Francis Marucco.
- Exercices de chimie des solides, Jean-Francis Marucco.

Master's Title: Materials Chemistry
Semester: 1
Teaching Unit Title: UED1
Subject Title: Environmental Protection I
Credits: 1
Coefficient: 1

Teaching Objectives

This course aims to raise awareness among chemists about the environmental risks associated with waste, greenhouse gases, and other pollutants. It emphasizes the role of chemistry in environmental protection and sustainable development.

Recommended Prerequisite Knowledge

Hygiene and safety in the laboratory

Course Content

(Detailed content for in-class and personal study)

Introduction

Chapter I : General Concepts of the Environment

- Definition of the environment
- Objectives of environmental analysis
- Impact of human activities on environmental systems
- Aquatic ecosystems
- Biodiversity
- Flora
- Fauna
- Factors contributing to biodiversity degradation

Chapter II : Sustainable Development Strategies

- Why sustainable development?
- Origins of sustainable development
- Implementation strategies for sustainable development

Chapter III : Environmental Protection – Algerian Legislation

- Environmental legislation: definition and scope

- Current legal framework for environmental protection and natural resource management
- Overview of relevant laws and regulatory tools in Algeria

Chapitre IV : Soil Treatment

- Soil overview: Concepts in pedology and soil quality
- Types of soil pollutants
- Mineral pollutants
- Organic pollutants
- Soil remediation methods
- Various treatment techniques (stabilization, containment, removal)
- Management of contaminated sites
- Legal frameworks and case studies

Evaluation Method

Final exam (written)

References

- Economie et politiques de l'environnement : Principe de précaution, Critères de soutenabilité, Politiques environnementales, Herve Deville.
- Analyse statistique des risques agro-environnementaux, David Makowski, Hervé Monod
- https://www.lebelage.ca/argent-et-droits/consommation-et-habitation/25-conseils-pour-proteger-lenvironnement?page=all
- https://www.unifr.ch/environment/assets/files/infos/FlyerSE.

Master's Title: Materials Chemistry
Semester: 1
Teaching Unit Title: UED1
Subject Title: English
Credits: 1
Coefficient: 1

Teaching Objectives

The main goal is to train future researchers to analyze scientific publications written in English in order to conduct bibliographic research related to a chosen research topic.

Recommended Prerequisite Knowledge

Basic knowledge of English

Course Content

- Oral expression and scientific terminology
- Understanding scientific literature (Structure and analysis of a scientific article)
- Oral communication practice through presentations followed by discussions
- Study of articles with scientific relevance
- Analysis of results presented in scientific articles written in English
- Scientific writing in English

Mode of evaluation : *Exam.*

References

https://www.sciencedirect.com/

https://www.sndl.cerist.dz/

Master's Title: Materials Chemistry
Semester: 1
Course Title: Computer Science
Credits: 1
Coefficient: 1

Course Objectives:

The student will become familiar with the main methods of Quantum Chemistry and will be able to interpret simulation results.

Recommended Prerequisites:

Quantum Chemistry and Computer Science

Course Content:

- Searching for scientific articles and documents on the Internet: Mendeley Desktop (Bibliography), Google Scholar, computerized databases.
- Use of the National Online Documentation System (SNDL) https://www.sndl.cerist.dz/
- Software: Origin (curves), HighScore Plus (XRD), PowDLL Converter XRD DATA, SpectraGryph1.2 (UV-VIS), Mendeley Desktop (Bibliography), etc.
- Introduction to scientific word processing (Word, Microsoft Equation Editor, chemical structure editors) and data processing using spreadsheet software (Excel, Origin, etc.)
- Methodology for presenting scientific work on a digital medium

Evaluation Method: Exam

References:

https://www.sndl.cerist.dz/
https://scholar.google.fr/
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: 2
Course Unit Title: UEF 1
Course Title: Electrochemical Analysis Methods
Credits: 5
Coefficient: 3

Course Objectives

This course aims to provide students with knowledge of both contemporary and traditional techniques used to characterize synthesized materials and electrochemical cells composed of various prepared materials.

Recommended Prerequisites

Electrochemistry
Solid-State Electrochemistry

Course Content

Chapter I: Voltammetric Methods

- ✓ Linear Sweep Voltammetry: Current-potential curves, curve equations, influencing factors.
- ✓ Amperometry: Principles, general concepts, amperometry with indicator and reference electrodes, biamperometry, instrumentation.
- ✓ Cyclic Voltammetry: Methods with linear potential sweep, principles, qualitative description of phenomena, theoretical aspects.
- ✓ Chronoamperometry: Principles, Cottrell equation, applications.
- ✓ Stripping Voltammetric Methods: Principles of anodic stripping, working electrodes used, quantitative and analytical aspects, cathodic stripping voltammetry, adsorptive stripping voltammetry.
- ✓ Application Examples.

Chapter II: Electrochemical Impedance Spectroscopy

- ✓ Definition and principles.
- ✓ Experimental setup and conditions.
- ✓ Equivalent electrical circuits.

- ✓ Application examples of electrochemical impedance.

Chapter III: Electrochemical Sensors

- ✓ Definition and basic structure of chemical sensors.
- ✓ General concepts regarding chemical sensors.
- ✓ Classification of chemical sensors.
- ✓ Faradaic (or amperometric) sensors.
- ✓ Conductometric sensors.
- ✓ Characteristics required for sensors.

Chapter IV: Electrochemical Biosensors

- ✓ General concepts of biosensors.
- ✓ Amperometric biosensors.
- ✓ Potentiometric biosensors.
- ✓ Conductometric biosensors.
- ✓ Application examples.

Mode of evaluation: E*xam, Continuous assessment*

References

- Méthodes Électrochimiques D'analyse. Auteurs Jean-Louis Burgot, Lavoisier, 2012.
- Les Réactions Électrochimiques, Méthodes Électrochimiques D'analyse. Auteurs : Charlot G.
- Techniques électrochimiques d'analyse. Auteurs : Maurice-Bernard Fleury, Martine Largeron.

Master's Title: Materials Chemistry
Semester: 2
Course Unit Title: UEF1
Course Title: Physical and Mechanical Properties of Materials
Credits: 4
Coefficient: 2

Course Objectives

- Describe the physical behavior of various classes of materials and the associated physical quantities.
- Differentiate between the electrical, optical, and thermal properties of conductors, insulators, and semiconductors.
- Estimate the order of magnitude of a material's electrical or thermal conductivity.
- Predict how a material's electrical or thermal conductivity evolves with temperature.

Recommended Prerequisite Knowledge

Adsorption phenomena

Course Content

Chapter I: Electrons and Photons

- **Drude Model:** Model description: Electron gas, collisions.
  Key physical properties: Electrical conductivity, thermal conductivity, interaction with electromagnetic radiation.
- **Sommerfeld Model (Quantum Electron Gas):**
  Model description: Free electron approximation, Fermi-Dirac distribution.
  Key physical properties: Electron heat capacity, electrical conductivity, Wiedemann-Franz law, free surfaces.
- **Energy Bands:**
  Model description: Electrons in periodic potentials, formation of forbidden bands, Kronig-Penney approximation.
  Key physical properties: Fermi surface, material classification.

Chapter II: Mechanical Properties

- Mechanical behavior of solids
- Elastic deformation of solids
- Plastic deformation of solids
- Quasi-static mechanical behavior
- Toughness and fracture
- Dynamic mechanical behavior
- Fractography

Chapter III: Densities and Thermal Properties

- Density
- Thermal expansion of solids
- Heat capacity
- Thermal conductivity

Chapter IV: Electrical and Dielectric Properties

- Review of solid-state structure
- Electrical conductivity
- Electrical conduction in metals
- Electrical conduction in semiconductors
- Electrical insulators

Chapter V: Magnetic Properties

- Basic concepts of magnetism
- Magnetic induction, permeability, and susceptibility
- Magnetization curve, hysteresis loop

Chapter VI: Optical Properties

- Interactions between photons and solids
- Absorption, reflection, refraction, dispersion
- Optical properties of metals and alloys
- Optical properties of non-metals

Assessment Method: Final exam and continuous assessment

References

- C. Kittel, Introduction to solid state physics, Wiley (2005)
- Michel, D. U. P. E. U. X. (2004). Aide-mémoire science des matériaux. Dunod, Paris, 89-130.
- W. D. Callister, Materials Science and Engineering: An Introduction, Wiley (2007).
- Moliton, A. (2007). Physique des matériaux pour l'électronique (pp. 437-Pages). Hermès-Lavoisier

Master's Title: Materials Chemistry
Semester: 1
Course Unit Title: UEF2
Course Title: Solid Analysis
Credits: 5
Coefficient: 3

Course Objectives

Interfaces between a solid phase and a fluid phase represent a highly anisotropic environment where specific chemistry takes place. This course will enable the student to describe solid surfaces from a textural perspective and determine their specific surface area (BET method).

Recommended Prerequisite Knowledge

Analytical Chemistry

Course Content

Chapter I: Radiation–Matter Interaction

1. **Radiations Diffracted by Crystalline Matter**
    - Nature of radiation – wave-particle duality
    - Relationship between energy and wavelength
2. **X-ray Production**
    - Synchrotron radiation
    - Excitation and de-excitation of inner atomic shells
    - Laboratory X-ray tubes for XRD
3. **X-ray–Matter Interaction**
    - Elastic interaction: Rayleigh scattering
    - Inelastic interaction: Compton effect, fluorescence
    - X-ray absorption

Chapter II: X-ray Analytical Techniques – X-ray Fluorescence (XRF)

- Principle
- Semi-quantitative analysis
- Quantitative analysis
- Sample preparation
- Application areas

Chapter III: X-ray Analytical Techniques – X-ray Diffraction (XRD)

1. **Coherent Scattering of X-rays**

- Scattering by a single electron: Thomson formula
- Scattering by an atom: atomic scattering factor

- Absorption effect: anomalous dispersion correction
- Thermal vibration effect: Debye-Waller factor

2. **Diffracted Intensity from a Periodic Structure**

- Conditions for constructive interference – Bragg's Law
- Nature of the scattering vector **R** – Ewald construction
- Diffracted amplitude – structure factor
- Friedel's Law
- Systematic extinctions

3. **X-ray Diffraction of Powders**

- General principle of X-ray powder diffraction
- Diffraction chambers
- Bragg-Brentano geometry diffractometer

4. **Global Simulation of a Diffractogram**

- Background intensity
- Peak positions
- Peak intensities
- Peak shapes and analytical profile functions used

5. **Powder Diffraction Databases Used**

- PDF (Powder Diffraction File)
- COD (Crystallography Open Database)

6. **From Qualitative to Quantitative Analysis**
7. **Particle Size and Microstrain Analysis**

Assessment Method: Continuous assessment and final exam

References

- Guinebretière, R. (2002). Diffraction des rayons X sur échantillons polycristallins. Hermès.
- Broll, N. (1996). Caractérisation de solides cristallisés par diffraction X. Ed. Techniques Ingénieur.
- Esnouf, C. (2011). Caractérisation microstructurale des matériaux: Analyse par les rayonnements X et électronique. PPUR Presses polytechniques.

Master's Title: Materials Chemistry
Semester: 2
Course Unit Title: UEM 2.1
Course Title: Advanced Chemical Kinetics
Credits: 4
Coefficient: 2

Course Objectives

- Understand that some reactions occur very slowly, while others are extremely fast.
- Recognize that a thermodynamically feasible reaction can still be extremely slow.
- Appreciate the practical and theoretical significance of chemical kinetics.

Recommended Prerequisite Knowledge

- Solution chemistry
- Chemical thermodynamics

Course Content

(This includes both in-class learning and required personal study)

Introduction

Chapter 1: Reaction Rate and Rate Laws

I. Reaction rate

II. Kinetic factors

III. Degeneracy of reaction order

Chapter 2: Reaction Mechanisms

I. Reaction mechanisms

II. Elementary reactions

III. Complex reactions

IV. Quasi-steady-state approximation (QSSA)

V. Reaction mechanisms and QSSA

Chapter 3: Experimental Methods in Chemical Kinetics

I. Chemical methods

II. Physical methods

III. Determining reaction order

III.1. Integral method

III.2. Differential method

III.3. Half-life method

III.4. Reaction order degeneracy

III.5. Relaxation techniques

III.6. Initial rate method

Chapter 4: Theory of Chemical Kinetics

I. Introduction

II. Collision theory

III. Transition state theory (activated complex theory)

Assessment Method: Continuous assessment and final exam

References

- Cinétique chimique - Eléments fondamentaux, Michel Soustelle, Hermes Science Publications 2011
- Réactions et réacteurs chimiques - Cinétique chimique, Cours et exercices corrigés, Michel Guisnet, Ellipses, 2007
- De l'oxydoréduction à l'Electrochimie, Y. Verchier, F. Lemaître Ellipses 2006
- Thermodynamique et cinétique chimique, Résumés de cours et exercices corrigés, Paul-Louis Fabre, Ellipses, 1998

Master’s Title: Materials Chemistry
Semester: 2
Course Unit Title: UEF 2
Course Title: Thermal Analysis Methods
Credits: 4
Coefficient: 2

Course Objectives

Thermal analysis methods (TAM) will provide students with fundamental knowledge used in the characterization of synthesized materials.

Recommended Prerequisite Knowledge

Thermal analysis

Course Content

Introduction: Review

Chapter I: Thermal Analysis

General principles of thermal analysis methods
Differential Thermal Analysis (DTA):
Principle
Instrumentation
Applications of DTA
Quantitative interpretation of a DTA curve
Factors affecting the curves, including position, magnitude, and shape of thermal events
Calorimetry:
Principles
Instruments and usage
Differential Scanning Calorimetry (DSC)

Chapter II: Thermogravimetry – Thermogravimetric Analysis (TGA)

Definition
Principle
Parameters obtained from TGA curves
Applications of TGA
Theoretical TGA curve profile
Main factors affecting TGA results
Kinetic interpretation of a TGA curve
Coupled Differential Thermal Analysis and Thermogravimetry

Chapter III: Dilatometry

Thermal dilatometry
Differential dilatometry

Assessment Method: Continuous assessment and final exam

References

- L'Analyse Thermique: Tome 2, A-P Bouaziz, R Rollet
- Thermal Analysis of Materials, Robert F. Speyer.

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

Course Objectives

Through this course, students will gain insight into various analytical methods of quantification.

Recommended Prerequisite Knowledge
Analytical Chemistry

Course Content

Part I: Analytical Chemistry Practicals

Lab 1: Complexometric titration of copper in aqueous medium

Lab 2: Determination of nitrates and chlorides in natural water

Lab 3: Removal of organic pollutants using an ion-exchange resin in aqueous medium

Part II: Structural Crystallography

Lab 1: Identification of unknown compounds using the ASTM database

Lab 2: Peak profile analysis of a powder diffraction diagram

Lab 3: Determination of crystal parameters from powder diffraction diagrams

Lab 4: Structure resolution and refinement (powder and/or single crystals)

Assessment Method: Continuous assessment and final exam

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

Course Objectives

Understand how to define the reaction rate and relate it to the rates of disappearance and formation of different species. Be able to analyze complex chemical systems composed of multiple reactions.

Prerequisite Knowledge

Students are expected to be proficient in mathematical tools, especially differential equations, as well as in the kinetics of simple reactions covered during the Chemistry Bachelor's program.

Course Content

Part I: Kinetic Studies

- Lab 1: Monitoring the kinetics of a chemical reaction via titration
- Lab 2: Monitoring the kinetics of a chemical reaction via conductometry
- Lab 3: Monitoring the kinetics of a chemical reaction via spectrophotometry

Part II: Electrochemical Techniques

- Lab 1: Linear sweep voltammetry
- Lab 2: Cyclic voltammetry
- Lab 3: Electrochemical impedance spectroscopy

Assessment Method: Lab reports and final exam

Master's Title: Materials Chemistry
Semester: 2
Course Unit Title: UED 1
Course Title: Materials for Energy Storage
Credits: 2
Coefficient: 1

Course Objectives

The student will be able to identify different types of renewable energy sources and select appropriate materials capable of replacing so-called noble materials.

Recommended Prerequisite Knowledge

Basic knowledge of electrochemistry and energy storage materials (ESM).

Course Content

Introduction

Chapter I: Electricity Storage

1. Mechanical storage
2. Electrochemical storage: batteries
3. Chemical storage: hydrogen

Chapter II: Thermal Storage

Chapter III: Materials for the Hydrogen Energy Sector

1. Specifications for hydrogen storage materials
2. Key properties of hydrogen storage materials
3. Implementation of hydrogen storage materials
4. Current challenges in hydrogen storage materials

Chapter IV: Materials for Photovoltaic Cells

1. All-organic photovoltaic cells
2. Dye-sensitized nanocrystalline solar cells
    - Principle
    - Materials
    - Fabrication of photovoltaic devices
    - Importance of morphology
    - Industrial development

Chapter V: Materials for Fuel Cells

Chapter VI: Environmental Applications

Assessment Method: Final exam

Références

Didier, N. O. Ë. L. (2014). Les nanomatériaux et leurs applications pour l'énergie électrique. Lavoisier.
https://www.techniques-ingenieur.fr

Master's Title: Materials Chemistry
Semester: 2
Course Unit Title: UET 1
Course Title: Environmental Protection II
Credits: 2
Coefficient: 1

Course Objectives

Chemists must be aware of the risks associated with waste, greenhouse gases, and other environmental threats.

Recommended Prerequisite Knowledge

Environmental Protection I, Hygiene and Safety.

Course Content

Chapter I: Water and Its Importance
Chapter II: Water and Aquatic Pollution
Chapter III: Water Treatment
Chapter IV: Recyclability and Recovery of Industrial Waste

- Global context of waste and recovery: definitions, waste typology, and regulations
- Stakeholders and their issues
- Various thermal waste treatment methods and associated recovery
- Recycling of ferrous and non-ferrous metals, management of steel industry by-products
- Recycling of oils and solvents
- Nuclear fuel cycle: recycling of spent fuel

Assessment Method: Final Exam

References

- Techniques de l'Ingénieur (http://www.techniques-ingenieur.fr/)
- Environmental Chemistry, 9th ed., Stanley E. Manahan, CRC Press, 2010.