REGULATIONS

ALLEGATO 2

INDUSTRIAL CHEMISTRY FOR CIRCULAR AND BIO ECONOMY

CLASSE LM-71

Interateneo : Università di Napoli Federico II – Politecnico di Torino

School : Scuola Politecnica e delle Scienze di Base
Department: Dipartimento di Scienze Chimiche

Regulations in effect as of the academic year 2022-2023

31/01/2022

Course : Complements of Inorganic and Organic Chemistry. Module 1 – Inorganic Chemistry		
SSD: CHIM/03		**CFU:** 5
Course year: 1	**Type of Educational Activity:** 3 CFU MOOC (Massive Open Online Courses), 1 CFU Lecture (On-line), 1 CFU Laboratory (in-person, attendance required)	

Content extracted from the SSD declaratory consistent with the educational objectives of the course: Atomic structure. Review of basic concepts: Structure of the hydrogen atom. Quantum numbers and atomic orbitals. Shape of the orbitals. Separation of sublevels in polyelectronic atoms. Electronic configurations and periodic table. Periodic properties: Atomic radii. Ionization energy, electron affinity, electronegativity and their periodic variation.

Chemical Bond. Ionic bond. Covalent bond. Lewis formulas of electronic structure. Formal charges and oxidation numbers. Resonance. Molecular geometry. Polarity. Molecular orbitals: Fundamental qualitative concepts with examples relating to homonuclear diatomic molecules.

Acids and Bases. Broensted acids and bases. Acid-base reactions. Conjugated couples. Polyprotic acids. Water self-protolysis: the pH. Strong acids and weak acids. Strong bases and weak bases. Leveling effect of the solvent.

The types of acids: aquoacids, hydroxyacids, oxoacids. Trend of acidity in HmEOn bone acids: Pauling's rule. Lewis acids and bases: classes of acids and bases. Lewis acid-base reactions. Hard-soft relationships.

Redox reactions. The oxidation numbers. Redox balance. Reduction potentials and their use in predicting chemical properties. Nernst equation. Water as an oxidant and a reducing agent: stability diagram. Disproportion and comproportion. Latimer and Frost diagrams.

Symmetry. Symmetry elements: identity, proper axes, symmetry plane, inversion center, improper axes. Symmetry groups and classification of molecules in symmetry groups.

Coordination compounds. Binders and complexes. π-acid complexes: alkenes and CO as ligands. Coordination numbers, geometries and factors that determine them. Examples. Isomerism and chirality in coordination compounds.

Electronic structure of the metal complexes of block d: Separation of the energies of the d orbitals and spectrochemical series in octahedral neighborhoods. High and low spin complexes. Representative elements and their main compounds.

Theoretical foundations and applications of X-ray diffraction.

Laboratory Experiences.

Learning objectives: The course aims to deepen students' knowledge in the fundamental aspects of both inorganic and organic chemistry. Specific learning objectives in this module are:

-Interpret the behavior of the elements of the periodic table and their compounds, with special emphasis on the study of bonding, acid-base, redox, and complexation reactions, and the correlations between structure of matter and ultimate properties.

-Solve basic problems concerning the behavior of the elements of the periodic table and their main compounds.

-Interpret complex phenomena, such as those in natural environments and industrial processes.

-Provide basic knowledge of the technique of X-ray diffraction as a method of structural investigation.

Propaedeuticities: None

Mode of conducting the examination: Verification by questionnaire/numerical exercise + final interview. The profit assessment is carried out in conjunction with that for the Inorganic Chemistry module of the same coure.

Course: Complements of Inorganic and Organic Chemistry. Module 2 – Organic Chemistry		
SSD: CHIM/06		**CFU:** 5
Course year: 1	**Type of Educational Activity:** 3 CFU MOOC (Massive Open Online Courses), 1 CFU Lecture (On-line), 1 CFU Laboratory (in-person, attendance required)	
Content extracted from the SSD declaratory consistent with the educational objectives of the course: General features of organic chemistry: how to draw an organic molecule, carbon-carbon bonds, chirality, diastereoisomerism, acids and bases in organic chemistry, classification of organic reactions. Nomenclature, structure, stereochemistry and reactivity of: alkanes and cycloalkanes, alkyl halides, alkenes, alkynes, aromatic compounds, alcohols, thiols, phenols, amines, aldehydes and ketones, carboxylic acids, esters, amides, anhydrides, acyl halides, thioesters. Structural features and chemical properties of major classes of biomolecules: carbohydrates, amino acids and peptides, nucleotides and nucleic acids, lipids. Theoretical foundations of nuclear magnetic resonance (NMR) and its application to structure determination of organic molecules. Laboratory Experiences.		
Learning objectives: The course aims to deepen students' knowledge in the fundamental aspects of both inorganic and organic chemistry. In this module, the specific educational objectives are: -Develop skills in understanding the structure and reactivity of organic molecules, based on their functional groups and stereochemical characteristics, with a special focus on classes of biomolecules fundamental to living organisms. -Provide basic knowledge of the nuclear magnetic resonance (NMR) technique as the main method of investigating the structure of organic molecules.		
Propaedeuticities: None		
Modalities of conducting the examination: Verification by questionnaire/numerical exercise + final interview. The profit assessment is carried out in conjunction with that for the Inorganic Chemistry module of the same teaching.		

Course: Complements of Physical and Analytical Chemistry. Module 1 – Physical Chemistry		
SSD: CHIM/02		CFU: 6
Course year: 1	Type of Educational Activity: 3 CFU MOOC (Massive Open Online Courses), 2 CFU Lecture (On-line), 1 CFU Numerical Exercises (On-line)	

Content extracted from the SSD declaratory consistent with the educational objectives of the course: Thermodynamics-The first law of thermodynamics: Relationship between molecular and macroscopic properties in ideal and real gases. Work and heat. First law. Enthalpy. Heat capacities. Expansion of ideal gases. Isothermal and adiabatic expansion. Thermochemistry. Hess's law. Standard enthalpies of formation. Dependence of enthalpy of reaction on temperature. The second law of thermodynamics: Spontaneous processes. Statistical and thermodynamic definition of entropy. The third law of thermodynamics. Entropy of typical processes. Spontaneity criterion and equilibrium condition. Phase equilibria: Rule of phases. One-component systems (pV diagrams). Chemical potential and molar partial quantities. Two-component systems. Liquid mixtures and vapor pressure (Raoult's and Henry's laws). Fractional distillation. Heterogeneous equilibria (solubility and eutectic points). Hints of colloidal systems and surface tension.

Chemical Kinetics- Experimental chemical kinetics: Rate of reaction. Kinetic laws in integrated form. Half-life. Effect of temperature on reaction rate. Numerical exercises.

Basics of Spectroscopy- Electronic states: atoms and molecules (diatomic and polyatomic). Molecular degrees of freedom: translation, rotation and vibration of molecules. Basics of spectroscopy. Introduction to electromagnetic radiation and basics of spectroscopy.

Numerical Experiences

Learning objectives:

The module is intended to provide students who lack it with the basic knowledge of physical chemistry and analytical chemistry in order to be able to take the subsequent courses provided by the LSC. In particular, the specific educational objectives of this are to provide:

-the knowledge the microscopic energy states and the distribution of internal and translational energy states as a function of temperature and molecular parameters.

-the understanding of absorption, emission and scattering spectroscopic techniques.

-a knowledge of the principles of equilibrium thermodynamics (Principles I, II and III) and the Mechanisms and devices of a thermodynamic description of gaseous chemical systems, liquid mixtures and solutions.

- the ability to apply Principles I and II to chemical systems of industrial interest.
- The ability to predict the spontaneity of processes from thermodynamic parameters.
- the ability to predict reaction rates from activation parameters.
- the knowledge of multi-stage kinetics with particular reference to enzyme kinetics. Numerical exercises will provide the tools for quantitative prediction of chemical and physical properties throughout the course

Propaedeuticities: None

Modalities of conducting the examination: Verification by questionnaire/numerical exercise + final interview. The profit assessment is carried out in conjunction with that for the Analytical Chemistry module of the same course.

Course: Complements of Physical and Analytical Chemistry. Module 2 – Analytical Chemistry		
SSD: CHIM/01		**CFU:** 5
Course year: 1	**Type of Educational Activity:** 3 CFU MOOC (Massive Open Online Courses), 1 CFU Lecture (On-line), 1 CFU Laboratory (in-person, attendance required)	
Content extracted from the SSD declaratory consistent with the educational objectives of the course: Introduction to the course. The sampling problem. Sample preservation. Analytical parameters of "quality". Calibration. Critical evaluation of results. Chromatographic techniques. Gas chromatography. Liquid chromatography. Mass spectrometry techniques (EIMS; MALDIMS, ESIMS). Sources and analyzers. Hyphenated and non-hyphenated analytical techniques: nano chip LC, GC, SPME/GCMS, ICPMS, Qualitative and quantitative analysis. The problem of false positives Laboratory Experiences.		
Learning objectives: The module aims to provide skills on the main instrumental analytical methodologies particularly used in research laboratories and industries. In addition, the main problems and parameters to be evaluated that condition the outcome of a laboratory examination are taken into consideration. The potential and critical issues of the various methodologies are illustrated by numerous examples. The student should be able to discriminate independently among the learned technologies which ones to apply and with which criterion for diagnostic purposes. He/she should also be able to evaluate and interpret experimental and literature data.		
Propaedeuticities: None		
Modalities of conducting the examination: Verification by questionnaire/numerical exercise + final interview. The profit assessment is carried out in conjunction with that for the Physical Chemistry module of the same course.		

<table>
<tr><td colspan="2">Course: Bioinorganic Chemistry and Industrial Enzymology. Module 1: Bioinorganic Chemistry</td></tr>
<tr><td>SSD: CHIM/03</td><td>CFU: 6</td></tr>
<tr><td>Course year: 1</td><td>Type of Educational Activity: 3 CFU MOOC (Massive Open Online Courses), 2 CFU Lecture (On-line), 1 CFU Laboratory (in-person, attendance required)</td></tr>
<tr><td colspan="2">Content extracted from the SSD declaratory consistent with the educational objectives of the course: Structure and function of proteins. Thermodynamics essentials of protein folding (Folding problem and dynamics of biomolecules).
Techniques for structural characterization of proteins (Crystallography, NMR, Electron Microscopy). Hints of Spectroscopy of biomolecules (Circular Dichroism, Fluorescence, Mass spectrometry). Methods of in silico characterization of biomolecules (Molecular mechanics and dynamics, docking). Chemical Kinetics and Enzymatic Kinetics.
Structure and function of metalloproteins and metalloenzymes of industrial interest. Design of proteins and metalloproteins, rational approach.
Laboratory Experiences.</td></tr>
<tr><td colspan="2">Learning objectives: The student must demonstrate knowledge of the problems related to the structure and function of proteins, and their production and characterization in industrial settings. He/she must demonstrate the ability to develop discussions on the methods to be used, starting from the notions learned about protein structure and function. The training aims to provide the student with the basic knowledge and methodological tools needed to purify and characterize a protein.</td></tr>
<tr><td colspan="2">Propaedeuticities: None</td></tr>
<tr><td colspan="2">Modalities of conducting the examination: The student should be able to design an experimental protocol to solve the questions posed to him or her, using the knowledge acquired during the course. The profit assessment is taken in conjunction with the assessment for the Industrial Enzymology module of the same course.</td></tr>
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<tr><td colspan="2">Course: Bioinorganic Chemistry and Industrial Enzymology. Module 2: Industrial Enzymology</td></tr>
<tr><td>SSD: BIO/10</td><td>CFU: 5</td></tr>
<tr><td>Course year: 1</td><td>Type of Educational Activity: 3 CFU MOOC (Massive Open Online Courses), 1 CFU Lecture (On-line), 1 CFU Laboratory (in-person, attendance required)</td></tr>
<tr><td colspan="2">Content extracted from the SSD declaratory consistent with the educational objectives of the course: Enzyme nomenclature (EC); the kinetic assay in theory and in practice; enzyme inhibition; use of genetic engineering to produce recombinant proteins; protein expression; cell lysis; protein fractionation; protein purification. Immobilization of enzymes on supports by covalent and noncovalent interactions. Application of proteins in industry.
Laboratory Experiences.</td></tr>
<tr><td colspan="2">Learning objectives: The student must demonstrate knowledge of the problems related to the structure and function of proteins, and their production and characterization in industrial settings. He/she must demonstrate the ability to develop discussions on the methods to be used, starting from the notions learned about protein structure and function. The training aims to provide the student with the basic knowledge and methodological tools needed to purify and characterize a protein.</td></tr>
<tr><td colspan="2">Propaedeuticities: None</td></tr>
<tr><td colspan="2">Modalities of conducting the examination: The student should be able to design an experimental protocol to solve the questions posed to him or her, using the knowledge acquired during the course. The profit assessment is taken in conjunction with the assessment for the Bioinorganic Chemistry module of the same course.</td></tr>
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<tr><td colspan="2">Course: Complements of Microbiology and Biotechnology. Module 1: Complements of Microbiology</td></tr>
<tr><td>SSD: AGR/16</td><td>CFU: 5</td></tr>
<tr><td>Course year: 1</td><td>Type of Educational Activity: 3 CFU MOOC (Massive Open Online Courses), 1 CFU Lecture (On-line), 1 CFU Laboratory (in-person, attendance required)</td></tr>
<tr><td colspan="2">Content extracted from the SSD declaratory consistent with the educational objectives of the course: The module illustrates the morphology, cytology, and physiology of microorganisms, with particular reference to their role in the bioeconomy; describes nutritional groups and microbial catabolism; provides a theoretical and practical overview of some of the main microbiological methodologies for the study of microorganisms; and introduces the ecological approach to the isolation and selection of microorganisms for use as a source of specific enzymes for the production of bioenergy and biochemicals.
Laboratory Experiences.</td></tr>
<tr><td colspan="2">Learning objectives: The course aims to provide students with cognitions useful in the exploitation and use of microbiological resources for the bioeconomy, introducing them to the fundamental aspects of microbial biotechnology and focusing on the use of microorganisms for the sustainable production of bioproducts.</td></tr>
<tr><td colspan="2">Propaedeuticicities: None</td></tr>
<tr><td colspan="2">Modalities of conducting the examination: Verification by questionnaire and possible oral test that may be used to meet special needs of the student. The profit assessment is carried out in conjunction with that for the Complements of Biotechnology module of the same course.</td></tr>
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<tr><td colspan="2">Course: Complements of Microbiology and Biotechnology. Module 2: Complements of Biotechnology</td></tr>
<tr><td>SSD: CHIM/11</td><td>CFU: 5</td></tr>
<tr><td>Course year: 1</td><td>Type of Educational Activity: 3 CFU MOOC (Massive Open Online Courses), 1 CFU Lecture (On-line), 1 CFU Laboratory (in-person, attendance required)</td></tr>
<tr><td colspan="2">Content extracted from the SSD declaratory consistent with the educational objectives of the course: The module describes the characteristics of the main microorganisms of biotechnological interest, the molecular strategies aimed at their improvement, and the different stages of the production process: from the formulation of the culture medium to the operational modes of fermentation and the main stages of product recovery. Examples of microbial bioprocesses aimed at the production of biomass, recombinant proteins, "bulk-chemicals" and biopolymers are explored.
Laboratory Experiences</td></tr>
<tr><td colspan="2">Learning objectives: The course aims to provide students with cognitions useful in the exploitation and use of microbiological resources for the bioeconomy, introducing them to the fundamental aspects of microbial biotechnology and focusing on the use of microorganisms for the sustainable production of bioproducts.</td></tr>
<tr><td colspan="2">Propaedeuticicities: None</td></tr>
<tr><td colspan="2">Modalities of conducting the examination: Verification by questionnaire and possible oral test that may be used to meet special needs of the student. The profit assessment is carried out in conjunction with that for the Complements of Microbiology module of the same course.</td></tr>
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Course: Circular Platforms for energy and materials recovery. Module 1: Raw Materials and Recycle	
SSD: CHIM/07	**CFU:** 5
Course year: 1	**Type of Educational Activity:** 3 CFU MOOC (Massive Open Online Courses), 1 CFU Lecture (On-line), 0.5 CFU Exercise (On-line), 0.5 Exercise (in-person, attendance required)
Content extracted from the SSD declaratory consistent with the educational objectives of the course: Strategies for raw materials and energy in the international and national outlook. Recycling and reuse of waste materials and by-products. Material recovery processes in civil contexts . Waste cycle in a systems approach. Integrated MSW management. Technologies and processes for material recovery from waste or industrial by-products (paper, glass, plastic, wood, aluminium, steel, etc.). Extraction processes of high value-added molecules. Valorization of the organic fraction of waste. Anaerobic digestion and composting. Raw materials for chemicals and energy. Widely used products and processes: paper, plastics, wood, food, glass and metals. The role of petroleum, energy and chemical expenditures. Non-renewable fuels and fossil sources: basic overviews of production, costs and prospects for development. Alternative fuels and renewable sources. Practical activities: how to write a successful project proposal in the circular economy sector, related evaluation criteria, scientific excellence and project impacts.	
Learning objectives: Identify possible scenarios for MINIMIZING WASTE or REFLUIT GENERATION by working on both process optimization and recovery/recycling strategies from industrial and civil contexts, identify the best technologies and SOLUTIONS FOR VALORIZATION of waste and by-products, evaluating both feasibility and economic and environmental sustainability, and finally technologies and processes for MATERIAL RECOVERY from waste to produce high value-added molecules.	
Propaedeuticities: None	
Modalities of conducting the examination: Students should be able to read a funding program and simulate the presentation of an innovative PROJECT PROPOSAL for obtaining public funding to write one in an original way. The assessment of profit with respect to the curricular content is carried out by questionnaire in conjunction with that for Module 2 Mass and Energy Balance for Circular Economy of the same course.	

Course: Circular Platforms for energy and materials recovery. Module 2: Mass and Energy Balance for Circular Economy	
SSD: ING-IND/25	**CFU:** 5
Course year: 1	**Type of Educational Activity:** 3 CFU MOOC (Massive Open Online Courses) 1 CFU Exercise (On-line) 1 CFU Exercises/Laboratory (in-person, attendance required)
Content extracted from the SSD declaratory consistent with the educational objectives of the course: Description of the main equipment in a chemical/biotech plant. Reading of Plant Flow-Charts. Mass and energy balances in chemical and biotechnological processes. Practical skills: solving problems related to mass and energy balances of chemical processes. Reading plant Flow-Charts.	
Learning objectives: It is intended to provide students with the ability to read plant schematics and to be able to make the relevant mass and energy balances that are essential for economic and environmental assessments.	
Propaedeuticities: None	
Modalities of conducting the examination: The assessment of profit with respect to the curricular content is carried out by means of a questionnaire/numerical exercise jointly with that for Module 1 Mass and Energy Balance for Circular Economy of the same course.	

Course: Industrial Chemistry	
SSD: CHIM/04	**CFU:** 8
Course year: 1	**Type of Educational Activity:** 6 CFU Lecture, 1 CFU Exercise, 1 CFU Laboratory
Content extracted from the SSD declaratory consistent with the educational objectives of the course: The Chemical Industry. Environmental and safety aspects of the chemical industry. The principles of Green Chemistry. The safety of chemical products (REACH). The certification of reduced environmental impact (Ecolabel). Patent protection in the Chemical industry. Industrial Catalysis. Kinetics of chemical reactions. Elements of Matlab. Case studies of the evolution of industrial processes toward lower environmental impacts. Integrated chemical/biotechnological industrial processes. Numerical and laboratory exercises in catalysis and kinetics.	
Learning objectives: The course curriculum aims to provide students with the in-depth knowledge and advanced methodological tools to analyze the fundamental aspects of industrial chemical processes and related issues of both science and technology.	
Propaedeuticities: None	
Modalities of conducting the examination: Verification by questionnaire/numerical exercise Students will also have to produce a written report on a chemical/biotechnological process based on a literature search. The content of the report will be presented by the student and will be the subject of the final interview.	

Course: Polymers: production, recycle and characterization	
SSD: CHIM/04	**CFU:** 6
Course year: 1	**Type of Educational Activity:** 5 CFU Lecture .1 CFU Laboratory
Content extracted from the SSD declaratory consistent with the educational objectives of the course: General classification of polymers in relation to synthesis processes: step-growth and chain-growth polymerization. General classification of polymers as thermoplastics, thermosets, rubbers and elastomers, and fibers. Properties of polymers in the solid state: Glass transition temperature and crystallization. Mechanical properties of polymers. Main techniques for characterizing the structure of polymers. Production processes and recycling of the most important thermoplastic polymers: polyethylene, polypropylene, polystyrene, polyvinyl chloride, polyesters and polyamides. Production processes and recycling of the most important thermosets: Phenolic and epoxy resins, curing and crosslinking methods. Production processes and recycling Rubbers and elastomers: natural rubber and synthetic rubbers. Thermoplastic elastomers. Polymers from renewable raw materials.	
Learning objectives: The objective of the course is to describe the most important industrial processes for the synthesis and recycling of polymers and to provide the basis for understanding the relationships between structure and properties	
Propaedeuticities: None	
Modalities of conducting the examination: Verification by questionnaire + final interview.	

Course: Industrial Biotechnology		
SSD: CHIM/11		**CFU:** 7
Course year: 1	**Type of Educational Activity:** 6 CFU Lecture, 1 CFU Laboratory	
Content extracted from the SSD declaratory consistent with the educational objectives of the course: Sustainability, Circular Economy and Bioeconomy, Biotechnology and Green Chemistry. Biomass, Microalgae, Biotransformation: enzymes and microorganisms, Biorefineries, Biomaterials and Bioplastics, Industrial Applications. Laboratory Experiences.		
Learning objectives: The course aims to provide knowledge related to industrial processes involving the use of biomass aimed at the design of innovative products and processes in the context of the circular economy.		
Propaedeuticities: None		
Modalities of conducting the examination: Verification by questionnaire/numerical exercise + final interview.		

Course: Green Unit Operations (reactors, separation units)		
SSD: ING-IND/25		**CFU:** 9
Course year: 1	**Type of Educational Activity:** 7 CFU Lecture , 1 CFU Exercises , 1 CFU Laboratory	
Content extracted from the SSD declaratory consistent with the educational objectives of the course: Introductory process analysis and design. Introduction to engineering of chemical and biochemical reactions. Continuous and discontinuous ideal reactors and their combinations. Reactor optimization for different chemical and biochemical kinetics. Reaction networks and optimization of reactor yield and/or selectivity. Mixing/segregation in homogeneous chemical/biochemical reactions. Mass transfer in homogeneous/heterogeneous chemical and biochemical reactors. Multiphasic Reactors. Investigation and rationale of reactors used in industrial processes: discussion of selected case studies. Introductory separation and purification technologies and their categorization. Basic selection criteria and design/operation guidelines. Fundamentals of process optimization. Techno-economic analysis - CAPEX and OPEX, Lang factor method, OPEX analysis in labor, services, materials, waste and consumables. Process optimization in the framework of industrial ecology: Life Cycle Assessment and Life Cycle Costing. Discussion of case studies.		
Learning objectives: The student will become familiar with: a) the basic criteria and guidelines for optimal selection of reactors and unit operations relevant to industrial process from the perspective of Green Engineering, and b) the basic analysis of industrial process flow diagrams. The process analysis will be demonstrated with reference to selected case studies relevant to green chemistry.		
Propaedeuticities: None		
Modalities of conducting the examination: Verification by questionnaire/numerical exercise + final interview.		

Course: Green Plant Design		
SSD: ING-IND/25		**CFU:** 11
Course year: 2	**Type of Educational Activity:** 8 CFU Lecture , 2 CFU Exercises , 1 CFU Laboratory.	

Content extracted from the SSD declaratory consistent with the educational objectives of the course:
Design of basic equipment for chemical processes: heat exchangers, adsorption columns, distillation units, liquid-liquid contactors, and chemical reactors. New equipment for innovative green processes (biochemical, membrane, enzymatic reactors). Overview of biotechnology products and processes: quantity, quality, fields of application. Characteristics of biocatalysts: interactions with engineering variables, actual behavior of biocatalysts, the problem of stress on biocatalysts, analysis of nutritional needs, micro and macro morphology. Production of biotechnology products: enzymatic, coupled with growth of microorganisms: primary, secondary, complex; internal to cells, external; liquid, gaseous. Bioreactor issues related to nature of biocatalyst: enzymatic, single microorganism, mixed populations, genetically modified; aerobic, anaerobic. Balances of matter and energy: stoichiometry of growth and product formation, prediction of transformation efficiencies. Bioreactor design equations: batch, fed-batch, continuous; effects of spatial non-uniformities on twin-jet performance; mixing and stress; performance analysis of different bioreactor types. Multiscale modeling and dynamics of bioprocesses: from pico reactor to large-scale reactor; use of fuzzy techniques in bioprocess modeling. Up-flow operations: growing media and raw materials, synthetic media: sources of C and N and micronutrients; formulation of complex media, culture broths; the problems of sterilization. Down-flow operations, fermentation product recovery: cell separation, product isolation from fermentation medium, product purification, final product isolation. Control of bioprocesses, sensors, measurements and chain of control: how and why. Examples of biotechnology products obtained by large-scale biotechnology: antibiotics, organic acids, enzymes; recombinant DNA biotechnology: production of interferon-γ; Adeno-associated Virus (AAV); energy biotechnology: bioethanol, methane, hydrogen; presentation and problems of two emerging bioprocesses: photobioproduction and bioelectrochemical systems (BES).

Learning objectives: Provide the basic knowledge for the development of equipment for innovative biotechnological chemical processes , providing the necessary biochemical and microbiological knowledge, understanding of bioreaction knowledge of the up-flow and down-flow operations of a biotechnological process. Application in the energy/environmental, medical/pharmaceutical and agribusiness sectors.

Propaedeuticities: None

Modalities of conducting the examination: Verification by questionnaire/numerical exercise + final interview.

Course: Industrial green process Simulation	
SSD: ING-IND/27	**CFU: 7**
Course year: 2	**Type of Educational Activity: 5** CFU Lecture , 2 CFU Exercices

Content extracted from the SSD declaratory consistent with the educational objectives of the course:

Process development through simulation. The importance of mathematical models for process description and analysis. Challenges and drawbacks in the practice of process simulation. Criteria for selection of simplified models. Selection of thermodynamic methods. Methods of presenting simulation results. Design and optimization of heat exchangers, adsorption or adsorption columns, distillation units, liquid-liquid contactors, and chemical reactors through a professional process simulator. Design of industrial chemical processes. Design and optimization of industrial processes with energy integration and internal recycling. Industrial applications of sustainable processes (biorefinery): production of bioethanol, bio-oil; biodiesel and biogas from different types of biomass (ligno-cellulosic, sugar, oil). Analysis and evaluation of energy consumption in equipment and engineering associated with innovative green processes. Definition of energy sustainability parameters and their use: ESI (Energy Sustainability Index) and EROI (Energy Return On Investment). Life cycle analysis (LCA) and energy sustainability. Technical-economic criteria for proper feasibility analysis of innovative processes. The energy balance over the entire biomass energy production cycle and the assessment of associated fossil and renewable CO2. Exercises: Material and energy balances on process schemes. LCA of products and/or processes: case studies of specific energy problems in biomass exploitation. Quantitative assessments.

Learning objectives:

To provide students with skills on model management, for process representation of individual equipment or entire plants, with the task of verifying the performance of new green processes, optimization of parameters, and presentation of simulation results, with special emphasis on the sustainability of innovative approaches proposed in the advanced chemical industry.

Propaedeuticities: None

Modalities of conducting the examination: Verification by questionnaire/numerical exercise + final interview.