Chimie ParisTech

SYLLABUS

2nd YEAR OF THE ENGINEERING CYCLE

The first semester of the second year presents the different fields of applications of chemistry: materials, polymers, biochemistry, energy)

The second semester offers a choice of five options in the second semester: analytical and biological chemistry (in English), processes, materials (in English), molecular chemistry, biotechnologies (in exchange with ESPCI). The lessons become more in-depth in each option.

The management courses focus on life and work in the company.

Students carry out an innovation project in a group throughout the year. This project is submitted by a client. The project is divided into three phases: inspiration, development, realization. During the first semester they write specifications and study the state of the art and literature (scientific, patent, internet). They develop an innovative proposal that they have validated by their steering committee. During the second semester they make a prototype proving the feasibility of their proposal.

Students do a five-month internship at the master level.

Semestre 3 :

Materials and processes (6 ECTS)
- Chemical reaction engineering and process safety
- Metallic materials
- Practical work in Metallurgy
- Experimental training in chemical engineering

Physical chemistry (6 ECTS)
- Thermostatics and Molecular Modeling
- Analytical physico-chemistry for bioanaysis and environment

Management : Human resources (6 ECTS)
- Human Resources Management
- English

Molecular and biological chemistry (6 ECTS)
- Biochemistry
- Polymer chemistry
- Practical courses in Polymer Sciences
- Practical courses in Biochemistry

- **Innovation and digital (6 ECTS)**
- Programming project
- Digital engineer
- Group innovation projects

Optional Courses
- Athens Week
- Sport
- Foreign languages

Semestre 4 :

<table>
<tr><td>1 option to be chosen</td><td>6 ECTS</td><td>6 ECTS</td></tr>
<tr><td>Analytical and biological chemistry</td><td>• Modern analytical chemistry for biotechnology and clinical diagnostics
• Chemistry probes for bioimaging
• Basic concepts of cellular biology
• Practical Biotechnology</td><td rowspan="2">• Bioinorganic Chemistry
• Molecular modeling
• Organometallic chemistry
• Energies Conferences</td></tr>
<tr><td>Molecular chemistry</td><td>• Heteroelements and applied catalysis
• Asymmetric Synthesis and Retrosynthesis
• Experimental training in molecular chemistry</td></tr>
<tr><td>Materials</td><td>• Physics III : Electronic Properties of Solids
• Surface properties and endurance of materials
• Inorganic materials elaboration
• Practical work in materials science</td><td rowspan="2">• Corrosion
• Inorganic chemistry: from molecules to materials
• Modeling
• Energies Conferences</td></tr>
<tr><td>Processes</td><td>• Process simulation
• Optimization and process control
• Flow chemistry
• Experimental training for flow chemistry</td></tr>
<tr><td>Biotechnologies</td><td colspan="2">Option occurring at the ESPCI engineering school</td></tr>
</table>

Management : Human resources (6 ECTS)

- Human Resources Management
- English

Professional project (12 ECTS)

- Internship 2A (5 months)

Optional Courses

- PSL Week
- Sport
- Foreign languages

SEMESTER 3

2A **S3**	**MH23ES.GC**	**Chemical reaction engineering and process safety** *Key words :* Chemical reaction engineering, Ideal reactors, Risk analysis methods (HAZOP, Event tree, failure tree, What if)

Responsible : Michael Tatoulian, C. Guyon, M. Zhang, S. Ognier, F. Rousseau, W. Benaissa (Solvay), Mickael Arnold (Sanofi), Vincent Piepiora (Total – Energo)
michael.tatoulian@chimieparistech.psl.eu

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* written exam
	22.5 h	3 h	h		

Course outline :
The concept "chemical reaction engineering" represents the approach required by the engineer to implement the transformation of selected reagents into desired products. As a result, the reactor combines the chemist's reaction mechanisms, which define the order of the steps necessary to obtain the desired products, with the transfer mechanisms (material, heat and quantity of movement) in order to allow the reaction mechanisms to be established with controlled kinetics, precise selectivity and defined reproducibility. The optimal implementation of chemical transformation requires knowing how to choose the most suitable reactor (batch reactors, continuous stirred tank reactor, plug flow reactor, continuous, discontinuous operation), and to define the operating conditions. First we will present the specificities of the different ideal reactors and their characteristic equations allowing to access the performances of the process (conversion, selectivity). Then we will approach situations closer to reality by taking into account the thermicity of the reactions by carrying out heat balances on these same reactors.
Finally, students will have to analyse the safety of chemical processes by using different process-specific risk analysis methods (HAZOP, What-if, Fault trees, event trees...).
These courses will be complemented by presentations by industrialists illustrating the issues of chemical process development in batch reactors (Sanofi), process instrumentation (Total) and process safety and thermal runaway issues (Solvay, INERIS).

Learning objectives :
At the end of the course, students must be able to :
Be able to understand the specificities of large industrial reactors
Be able to write a material balance and a heat balance in the case of ideal reactors
Be able to dimension a reactor and calculate its performance
Be able to ensure the operational safety of a process by using risk analysis methods

Prerequisites :
general chemistry- Kinetic

Teaching language : french
Documents, website : handouts https://coursenligne.chimie-paristech.fr

2A S3	MH23ES.MM	**Metallic materials** *Key words :* Metallurgy, alloys, phase diagrams

Responsible : Frédéric PRIMA Professeur
frederic.prima@chimieparistech.psl.eu

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* written examination
	21 h	3 h	14 h		

Course outline :
The objective of this course is to provide students with a foundation in structural metallurgy.
It addresses various related aspects:
Microstructures of metal alloys: structural aspects (defects), chemical aspects (diffusion), thermodynamic aspects
The study of structure/property relationships (introduction)
To the solidification of alloys (the genesis of these microstructures)
Phase diagrams (binary and ternary)
Phase transformations: kinetic, thermodynamic and crystallographic aspects
Industrial processes for the manufacture of metallic materials (thermomechanical treatments)
The course is completed by 2 days of practical work on metallurgy illustrating the relationship between microstructure and mechanical properties (hardening and tensile studies)

Learning objectives :
At the end of this course, the student masters the different concepts of metallurgy.
He knows how to make the link between thermodynamic aspects and microstructures of metallic materials
It understands the relationship between the microscopic aspects of a material and its macroscopic properties in terms of mechanical behaviour.
He can develop a synthesis strategy in relation to the expected properties of an alloy.

Prerequisites :
bachelor level in thermodynamics and solid state chemistry

Teaching language : french
Documents, website :

2A S3	MH23FE.GC	**Experimental training in chemical engineering (2nd year)** *Key words :* Chemical engineering, reactors, unit operations, processes, simulation, Hysys, Comsol

Responsible : Frederic Rousseau Associate Professor
frederic.rousseau@chimieparistech.psl.eu

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* written reports (work synthesis and skills assessment)
	0 h	0 h	22.5 h		

Course outline :
The objective of this Teaching is to put into practice the notions of chemical engineering that students have acquired in the first year and during the first semester of the 2A. Students, in groups of three, pilot and study experimental pilot installations (tubular or stirred tank reactors, calorimeter type DSC). This allows students to influence the properties and particularities of the main reactors used in chemistry. They also discover the principle of acquiring kinetic measurements of chemical reactions using calorimetry. Finally, they build industrial process simulations using ASPEN HYSYS and COMSOL software in steady state mode. In this way, students learn good simulation practices in chemical engineering and acquire the concepts of degrees of freedom. They also learn to remain critical of the results obtained by these tools.

Learning objectives :
At the end of the teaching, the student will be familiar with the specificities and properties of chemical reactors used in research and industry. It will be suitable for the implementation of kinetic measurements from a DSC type calorimeter. It will also be able, depending on the complexity of the problem, to select the most relevant software to study a single reactor or a complete process in steady state.
The student will master a know-how consisting in the construction and optimization of a stationary simulation including a reactor and various operations of pressure build-up, heating, separation, purification... He will be able to remain critical towards the hypotheses formulated and the results obtained from simulation tools.

Prerequisites :
notions of transfers of quantity of movement, matter and energy / unit operations / reactor calculations

Teaching language : french
Documents, website : handouts and pdf documents

2A S3	MH23ES.BIO	**Fundamentals of Biochemistry** *Key words :* biochemistry, protein, enzymology, nucleic acid, carbohydrate, lipid

Responsible : Olivier Ploux Professeur
olivier.ploux@chimieparistech.psl.eu

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* Written exam of 1:30 h (no documents, no electronic calculator)
	16.5 h	6 h	0 h		

Course outline :
This course describes the fundamental molecular processes that take place in living cells. We shall describe the structure and function of the major biological macromolecules. The flux of information in the cells and the evolution principles will be discussed. Non-covalent interactions; Proteins: structure and function; Enzymology: fundamental enzyme properties and applications; Nucleic acids: structure and function; replication; transcription, translation; Carbohydrates: structure, reactivity, and function; Lipids and biological membranes.

Learning objectives :
After attending this course, the student should know the main non-covalent interactions that are important in life sciences: electrostatic, Van der Waals, hydrogen bonds, hydrophobic interactions.
The student should be able to describe the primary, secondary, tertiary and quaternary structure of proteins as well as defining the native structure and its main properties.
The student should be able to describe Michaelis-Menten enzyme kinetics, explain how enzyme works (catalysis type, reaction mechanism of typical proteases) and to understand the effect of reversible competitive inhibitors on enzymes and of covalent inhibitors.
The student should be able to describe the structure of nucleic acids (DNA and RNA) and the mechanism of the flux of information transfer in the cell (replication, transcription, translation), and the synthesis of deoxy-oligonucleotides, a PCR experiment, and the DNA sequencing by the Sanger method.
The student should be able to describe the structure of hexoses and ketoses (from three carbons to six carbons; Fischer projection, Haworth representation and chair conformation), to know their reactivity (cyclization, mutarotation, isomerization)
The student should be able to describe the structure of simple lipids and of their main components (fatty acids, triglycerides, phospholipids) and to describe the structure of the bilayer membrane and the main functions of the biological membranes.

Prerequisites :
Structural chemistry: atoms, molecules and covalent bonds; bond electronic polarization; mesomery; non-covalent interaction incl

Teaching language : french
Documents, website : pdf document of the slide presentation

2A S3	MH23ES.POL	**Polymer Chemistry** *Key words :*

Responsible : THOMAS Christophe Professeur
christophe.thomas@chimieparistech.psl.eu

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* Basic principles of organic chemistry
	12 h	10.5 h	0 h		

Course outline :

This course introduces the basics of the major methods of polymer synthesis. This course provides students with the fundamental tools necessary to understand the structure/property relationships of polymers. This course also shows students how the control of polymerization reactions by a judicious choice of initiator or catalyst systems and experimental synthesis conditions can produce perfectly defined macromolecular structures and architectures.

Learning objectives :

At the end of the course, the student will be able to use the major concepts of polymer chemistry and propose methods suitable for the characterization of polymers in solution and in solid state and to control them for some of them (DSC, SEC, RMN, MALDI-ToF).

Prerequisites :

Teaching language : **french**

Documents, website :

2A S3	MH23FE.POL	**Pratical Courses in Polymer Sciences** *Key words :* polymers, soft matter, radical polymerization, ROP, biodegradable polymers

Responsible : Carine Robert Maître de Conférences
carine.robert@chimieparistech.psl.eu

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* Writing report about the results of the project
	0 h	0 h	22.5 h		

Course outline :
Practical courses in polymer sciences. One project is studied by two-person team for three days from purification of starting materials to controled synthesis and study of physico-chemical properties of a shaped object (NMR, DSC, SEC).

Learning objectives :
The student will be able to carry out a synthesis of polymerization linked to the desired properties of the material (thermoplastic, thermoset, elastomer, hydrogel, biodegradable polymer).

Prerequisites :
Polymer Sciences S3

Teaching language : french
Documents, website : handouts https://coursenligne.chimie-paristech.fr/course/view.php?id=295

2A S3	MH23FE.BIO	**Practical course in Biochemistry** *Key words :* Proteins, DNA, Extraction, analysis

Responsible : Corinne MARIE
corinne.marie@chimie-paristech.fr

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* The rating is based on the evaluation of a report and the assessment of the student's skills
	22.5 h	0 h	0 h		

Course outline :
The modification of living organisms has become a major strategic challenge for the optimisation of many industrial processes. As part of this experimental training, we wish to introduce different techniques commonly used to modify and analyze the DNA or proteins of a cell. We also aim to illustrate the knowledge covered during the lectures of Biochemistry.

Learning objectives :
At the end of the training, the student will be able to extract and analyze two major groups of biomolecules such as proteins and DNA whose structures and characteristics have been covered in the Biochemistry course. The student should also conduct bibliographic research to determine the limits of the proposed techniques and, if necessary, propose alternative protocols, specifying their advantages and disadvantages.
In addition to the acquisition of new techniques, the student should summarize the experimental results obtained by discussing them and comparing them with bibliographic data.

Prerequisites :
Knowledge of the DNA and proteins structures and major cell compartments that were presented during the Biochemistry course

Teaching language : french
Documents, website : handouts and slide presentation

2A S3	MH23ES.TMM	**Thermostatics and Molecular Modeling** *Key words :* molecular modeling

Responsible : Carlo Adamo Professeur
carlo.adamo@chimie-paristech.fr

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* Written exam
	10.5 h	7.5 h	0 h		

Course outline :
This module aims to train the engineering student in the main molecular modelling methods.
The main concepts covered are: classical methods (mechanical and molecular dynamics) for the description of matter (from molecule to biosystems) as well as their coupling with ab-initio or semi-empirical quantum methods, the description of the chemical environment with particular attention to solvating methods, and the exploration of surfaces of potential energy.
The training is based on alternating course and TD sessions. During the TDs, using calculation software, students can apply the illustrated methods in class to predict the solvation and reactivity of simple organic systems.

Learning objectives :
The student must be able to:
- know the basics of molecular mechanics and molecular dynamics
- choose the most suitable method to model the environment (solvent)
- know how to describe chemical reactivity

Prerequisites :

Teaching language : french
Documents, website : handouts

2A S3	MH23ES.PCA	**Analytical physico-chemistry for bioanaysis and environment** *Key words :* sample treatment, separation, detection, trace or even ultra-trace analysis

Responsible : Varenne Anne Professeur
anne.varenne@chimieparistech.psl.eu

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* Multiple choice questions, Written report and oral presentation of the project
	24 h	0 h	0 h		

Course outline :
Theoretical courses cover the most important methodologies in all areas requiring monitoring and analysis, allowing access to quantitative information and interaction in solutions. These are essentially separative and electroanalytical methods, in classical or miniaturized form. The aspects of separation, sample processing, coupling of separative methods with sensitive and specific detection methods (fluorescence, mass spectrometry...) are thus addressed. In addition, the theme "quality control" is presented, including standards, traceability and life cycle analysis. The engineer is increasingly being asked to control the purity and stability of a product by traceable methods (analytical traceability of measurements, validation of a method, sampling, calibration, statistical methods, reporting and archiving, regulation, proficiency testing), with a view to their accreditation by the standards, which are now at an international level. In the context of sustainable development, the life cycle analysis (or ecobalance) of products is presented.
The module consists of project work (6 to 7 students per project) with the support of a theoretical teaching support available online and conferences given by specialists in different fields. The objective of this project is to find in the scientific literature methods (electrochemical, chromatographic and electrophoresis) to quantify traces/ultratraces (synthetic impurities, pollutants, biomolecules for pharmaceutical application...) in complex matrices, defined by the project. The different methods selected will be compared in terms of precision quality, ease of analysis, etc....... and a choice will be made on the most appropriate method.

Learning objectives :
The objective of this module is to obtain a complete and critical overview of the different methodologies for trace or ultra-trace analysis in complex matrices (biological or environmental). The student must find, analyse and criticize the existing bibliography in the proposed field, then use his knowledge to select the most appropriate method or even be a force of proposal to imagine a new methodology. All the steps of an analytical method are studied (sampling, processing, separation, detection).

Prerequisites :
Concepts from the courses of solution chemistry, separation methods, electrochemistry, physico-chemistry at the interfaces of 1A

Teaching language : french
Documents, website : english articles

2A S3	MH23FE.PI	**Programming project** *Key words :* project, numerical, C

Responsible : Frédéric Labat Maître de Conférences
frederic.labat@chimie-paristech.fr

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* Written report and oral presentation.
	0 h	0 h	45 h		

Course outline :
This module aims to train the engineering student to solve a concrete scientific problem requiring the development of a computer application. By working in pairs, it also aims to learn to work in a team and to present its work in a clear and concise manner, in the form of a written report and an oral defense using a slide show.
The proposed projects are chosen in various fields such as chemistry, physics, biochemistry, computer graphics, or cryptography. They aim to develop the following skills:
- analysis of a scientific subject and choice of resolution method
- translation of the problem into computer language
- program coding and validation
- scientific analysis of the results obtained

Learning objectives :
The student must be able to:
- analyse a scientific subject and choose the method of resolution
- translate a scientific problem into computer language
- code and validate a program
- scientifically analyze the results obtained

Prerequisites :
C programming: basics and algorithms

Teaching language : french
Documents, website :

2A S3S4	MH23TC.PIG MH24TC.PIG	**Group innovation project** *Key words :*

Responsible : Philippe Barboux Professeur
philippe.barboux@chimieparistech.psl.eu

ECTS :	*Course* h	*Tutorials* h	*Practical work* h	*Mentoring*	*Evaluation method :* report 50% Oral presentation 50%

Course outline :

The purpose of these projects is to learn project management and teamwork through the development of a technological innovation project. A technological project is a study aimed at developing an idea initiated by a "customer", which must result from an innovation process aimed at creating "a new product, a new service, a new good", adding that a new process or a new recipe closer to chemistry can be included.

Project progress Projects are divided into five phases

1) Research of topics and organization of the team and project
2) Study of the state of the art and analysis of resources (patents, publications, internet, customer visit, etc.)
3) Elaboration of the project and proposal phase to the steering committee. Circus discussion and defence of the project. Possible order of equipment
4) Technical implementation, development
5) Restitution (video 10 minutes or report writes 15 pages then oral defense of the project.

Learning objectives :

The objective of learning is to learn to develop interdisciplinary skills in the field of project management (timetable, programming) and in the scientific and technical field (analysis of the state of the art, bibliography, initiative, design and development of an innovative product)

Prerequisites :

Teaching language :
Documents, website :

<table>
<tr><td>2A
S4</td><td>MH24TC.MRT</td><td colspan="4">Human ressources management and Management
Key words : management, leadership, HRM, SPR and occupational health, diversity, labour law</td></tr>
<tr><td colspan="6">Responsible : Philippe Vernazobres Maître de conférences
philippe.vernazobres@chimieparistech.psl.eu</td></tr>
<tr><td>ECTS :</td><td>Course
24 h</td><td>Tutorials
13 h</td><td>Practical work
h</td><td>Mentoring</td><td>Evaluation method : writing a skills assessment + MCQ</td></tr>
</table>

Course outline :
This course covers the main aspects of human resources management and management, useful to an engineer for his integration in a professional context and the performance of his duties:
- Being a Manager and working with HR
- Recruit and be recruited
- Developing talents and teams
- Managing careers and promoting diversity
- Motivate and be motivated
- Develop leadership and influence
- Manage time, delegate and make decisions
- Being involved in well-being and health at work: preventing psychosocial risks (PSR) and promoting quality of life at work (QWL)
- Understanding Labour Law

In addition to the courses, three half-day workshops - in groups of 15/20 students - are organised to prepare them to approach the labour market and the search for internships: WS1 : Skills assessment - WS2 : Job interviews - WS3 : Assesment Centers.
Finally, in order to know themself better, each student is invited to take the MBTI, a questionnaire designed to understand their psychological preferences and preferred ways of working, which is widely used in companies.

Learning objectives :
At the end of the course, the student will be able to:
• Understand the challenges and practices of management and leadership, and implement them in the context of engineering work.
• Understand, analyze and apply HR processes as an engineer, and work in collaboration with HR professionals.
• Understand the challenges and practices of RPS prevention, and implement them as an engineer, in the service of health and Quality of Life at Work (QWL).
• Apply for a job or an internship (interviews, Assesment Center...)
• Understand the overall framework of labour law.
• Analyze an employment contract and understand its legal consequences.
• Know yourself better, self-assess yourself, develop your skills (soft skills): become aware of your managerial and leadership resources and develop them, through the proposed mechanisms: MBTI, skills assessment....

Prerequisites :
Attending and validation of the school's 1st year management courses. Or equivalent for students entering the 2d year of the school.

Teaching language : french
Documents, website : handouts

2A S3S4	MH23TC.ANG; MH24TC.ANG;	**SCIENTIFIC AND BUSINESS ENGLISH** *Key words :* English, Scientific, Business, Intercultural Skills

Responsible : Daria Moreau Chargée de mission langues et management commercial
daria.moreau@chimieparistech.psl.eu

ECTS :	*Course* 0 h	*Tutorials* 30 h	*Practical work* 0 h	*Mentoring*	*Evaluation method :* Validation of 5 skills (see CECRL grid) at least at B2/C1 level

Course outline :

English classes aim to improve English skills and teach linguistic autonomy in order to prepare students to use technical and scientific English in an international and intercultural professional context.

The classes take place in level groups established at the beginning of the year on the basis of both a placement test and oral evaluations. For the most advanced students (bilingual or C2 according to CECRL) it is possible to replace the classroom courses with research work supervised by a teacher from the Department. Low-level students may attend one-to-one tutoring sessions.

The classroom courses are complemented by an adapted and varied "e-learning" (the Yesmag application which aims to facilitate reading texts in their original versions; multiple linguistic activities on Moodle; self-study in the language lab).

English courses are to master:

- debates on any subject (cultural, economic, technical, scientific, etc.), without prior training or special training in order to be part of a joint oratory team,
- discussions on cultural topics specific to Anglo-Saxon countries as well as on scientific articles,
- presentations of authentic projects carried out as part of cross-curricular courses,
- the practice of oral and written comprehension skills,
- the synthesis and comparison of authentic technical documents,
- analysis of internship offers in English-speaking countries and simulations of job interviews,
- writing cover letters,
- technical and scientific vocabulary,
- writing reports on a wide range of topics,
- TOEIC preparation exercises (a TOEIC mock exam will take place at the end of each semester).

Learning objectives :

The student will increase his/her in-depth knowledge of grammar and thematic and scientific vocabulary by communicating flawlessly in both written and oral business English in a multicultural company / The student will be able to quickly access sources of internship or employment opportunities, analyse and synthesize the employer’s expectations and respond in English to the offer of interest / The student will write in English a cover letter and/or a video CV to the internship offer of his/her choice, taking into account the cultural rules of an English-speaking country / The student will be open to collaborative work / The student will have a strong culture of at least one English-speaking country / The student will give a 15-minute-long presentation without notes on his/her transversal project (with or without Power Point) / The student will participate in a debate on an everyday life, technical or scientific subject / The student will answer factual questions on a given subject / The student will synthesize a scientific text or an audio, identify relevant information and present it to an audience / The student will understand the structure of the TOEIC test and develop his/her personal strategy to maximize his/her exam score.

Prerequisites : B2

Teaching language : English
Documents, website : audio and video documents, factual documents https://coursenligne.chimie-paristech.fr/course/view.php?id=31

SEMESTER 4

2A S4	MH24ES.ENE	**Energies Conferences** *Key words :* Energy transition, renewable energy sources, nuclear energy, hydrogen, intermittency, electricity grid

Responsible : GERARD COTE Professeur
gerard.cote@chimieparistech.psl.eu

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* Student attendance monitoring and final multiple-choice questionnaire
	15 h	0 h	0 h		

Course outline :
The ENERGIES course underlines the challenges to overcome to make acceptable the energy transition and provides a critical overview of present and emerging available energy systems

Learning objectives :
At the end of the course, the student will have
- understood the challenges of the energy transition
- acquired an overview of the strengths and weaknesses of present and emerging available energy systems
- understood how electricity grids work and the difficulties to integrate intermittent renewable energies

Prerequisites :
Chemistry and physics level bachelor

Teaching language : french
Documents, website : pdf documents https://coursenligne.chimie-paristech.fr/enrol/index.php?id=306

ANALYTICAL and BIOLOGICAL CHEMISTRY - ABC OPTION

2A **S4**	**MH24OP.CBI**	**Bioinorganic Chemistry** *Key words :* Medicinal Inorganic Chemistry, Bioorganometallic Chemistry, Bioinorganic Chemistry, Inorganic Chemical Biology.

Responsible : Gilles Gasser
gilles.gasser@chimieparistech.psl.eu

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* Written Exam.
	15 h	0 h	0 h		

Course outline :
Nature utilizes metal ions and metal complexes to undertake several crucial processes. In fact, a human being requires about 25 elements to have a healthy life, half of them being metals! The chemical study of metals in biology is referred as bioinorganic chemistry. This area of research encompasses the study of metallo-enzymes (i.e. vitamin B12) or biological processes such as respiration. In this course, a general overview of the role of metals in biology will be presented. It is also planned to outline to role that metal complexes can play to understand biological processes.

Learning objectives :
The course will be divided into two main sections. In the first section, the role of metal ions in a few key metalloproteins and biological processes will be explained. The second section will focus on the use of metal complexes to detect specific organelles/biomolecules, or a discussion to understand/modify biological processes. A large emphasis will be placed on experiments, which have been carried out in living cells or organisms.

Prerequisites :
This course requires basic knowledge of inorganic chemistry and biochemistry.

Teaching language : english
Documents, website :

2A S4	MH24OP.MOM	**Molecular Modeling** *Key words :*

Responsible : Carlo Adamo Professeur
carlo.adamo@chimieparistech.psl.eu

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* Written report
	4.5 h	0 h	9 h		

Course outline :
This module aims to train the engineering student in quantum and classical modelling of complex systems (molecules, solids, biomolecules) of industrial interest. The methods used to describe spectroscopic properties (IR, Raman, UV-Vis, NMR and EPR) and chemical reactivity are particularly targeted.
Particular interest is given to simulation methods currently used in the industrial and application field, and their use is illustrated by courses and seminars given by two external speakers from public or private institutions presenting their activity, in order to strengthen the link between modelling and the business world.
The training is based on alternating course and TP sessions, which allow students to put into practice the methods described in class using software of academic and industrial interest.

Learning objectives :
The student must be able to:
- choose the most suitable method according to the properties and system targeted
- interpret the results obtained and their limitations
- interact with modelling experts

Prerequisites :

Teaching language : french
Documents, website : handouts

2A S4	MH24OP.COM	**Organometallic Chemistry** *Key words :*

Responsible : THOMAS Christophe Professeur
christophe.thomas@chimieparistech.psl.eu

ECTS :	*Course* 7.5 h	*Tutorials* 7.5 h	*Practical work* 0 h	*Mentoring*	*Evaluation method :* Written examination

Course outline :

This course describes the fundamental reactions of transition metal complexes and some (industrially relevant) catalytic cycles. This course provides an introduction to catalysis as a tool for the development of clean and energy efficient synthesis processes.

Learning objectives :

The first objective of this course is to rationalize the reactivity of catalytically generated molecules and intermediates. The second objective is to develop a catalytic cycle in organometallic chemistry and to determine the appropriate analytical methods for the mechanistic study of a catalytic reaction by transition metal compounds.

Prerequisites :

Teaching language :
Documents, website :

2A S4	MH24OP.BIA	**Modern analytical chemistry for biotechnology and clinical diagnostics** *Key words :* analytical systems, process miniaturization, engineering, innovation

Responsible : Fanny d'Orlyé Maître de conférences
fanny.dorlye@chimieparistech.psl.eu

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* final written exam with documents
	10.5 h	9 h	4.5 h		

Course outline :
The developments and trends in modern analytical chemistry are going toward process simplification, automation and miniaturization while preserving the performance and reliability of analytical results. Possibilities and difficulties inherent in miniaturization at each step of an entire analytical process are quite different and should be addressed. Thus, the main goal of this course is to provide a comprehensive overview of the current innovations in the field of analytical systems. The final objective is presented as the development of micro(nano)sensors and micro total analysis systems (µTAS) for biotechnology and clinical diagnostic applications.

Learning objectives :
The course will focus on new analytical and bioanalytical tools allowing the downsizing of several laboratory functions (sample introduction, treatment, separation, detection) in order to handle extremely small fluid volumes but also to integrate aforementioned lab processes on a miniaturized device of a few square centimeters to achieve automation and high-throughput screening. The main topics of concern for the students will be 1) New functionalized nanomaterials for diagnosis: nano-supports (nanoparticles, nanotubes, monoliths, molecular imprinted materials …), selective agents (antibodies/proteins, aptamers, chelating agents…) and conjugation procedures; 2) Developments in miniaturized separation methods (chromatographic or électrokinetic) mainly based on molecular recognition to purify, concentrate and isolate analytes of interest; 3) Detection in miniaturized analytical systems (optical, electrochemical, mass spectrometry); 4) Analytical applications on going from standard bioassays to micro(nano)sensors and µTAS for biotechnology and clinical diagnostics.

Prerequisites :
basic notions in thermodynamics of solutions, non-covalent interactions, colloïds, electrochemistry and separation méthods

Teaching language : french
Documents, website : handouts, publications and quiz in english (website)

2A S4	MH24OP.CHE	**Chemistry probes for bioimaging** *Key words :* Bioimaging, chemical probes, fonctionalizing

Responsible : Bich Thuy Doan Chercheur CNRS
bich-thuy.doan@chimie-paristech.f

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* written examination
	21 h	0 h	2 h		

Course outline :
The field of medical imaging has become a real specialty and cutting-edge research is perfectly adapted to the activities of university and industrial laboratories. The development of this discipline is closely linked to the active development of new probes to target or probe pathological biological tissues in order to establish a quantitative diagnosis. This diagnosis is evaluated in vitro, in vivo in preclinical to clinical studies and associated with industrial production.
The following fields of imaging will be covered by chemists or biophysicists: Ultrasound, Magnetic Resonance, Nuclear Medicine, Optics, Nanoparticle Agents, Theranostics Probes (imaging + drug). In addition, molecular and physico-chemical characteristics will be represented.
Finally, some in vivo biological applications for the detection of cancer, inflammation and the impact of treatment will illustrate the interest in the diagnosis and therapy of functionalized probes.

Learning objectives :
The student is familiar with all commercial imaging probes used in bioimaging as well as their in vitro and in vivo applications in the biomedical or medical field.
It includes their operating principles, and the biophysical or biochemical principles of their operation.
In the case of molecular probes, he can propose innovative solutions to develop them and explain how functionalized probes can be developed.

Prerequisites :
at least bachelor degree in physical chemistry and molecular chemistry

Teaching language : english
Documents, website :

2A S4	MH24OP.BIC	**Basic concepts of cellular biology** *Key words :* Cell biology, Microbiology, Toxicology

Responsible : MINIER Michel
michel.minier@chimieparistech.psl.eu

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* written examination
	24 h	4 h	0 h		

Course outline :
This course teaches the basic knowledge on cell structure, physiology, microbiology, protein biochemistry and toxicology.
The structure and physiology of typical living cells will be presented, in order to clarify the shared features and the differences between bacteria, yeasts, microalgae, archaea, vegetal cells, mammal cells. Industrial applications are discussed.
The lectures will also present the basic principles and the applications of instrumental and molecular methods used for the analysis of biomolecules.
A focus will be made on toxicology. This starts with the knowledge of the basic biological mechanisms involved when a toxic (toxin, medicine, etc…) is absorbed by the organism.

Learning objectives :
At the end of this introductory course, the student must know the basics of cellular structures, physiology and microbiology.
The students understands the physiology and the exchange of matter and energy within a cell.
He knows the biochemical effects of the toxicological properties of proteins.
He is aware of the importance of biology at the interface of the physical and chemical sciences and understands the challenges and role of life in industrial applications: biotechnologies aimed at producing chemical components, fuels and bio-sourced materials, cosmetic industries in search of "natural, sustainable and safe" ingredients, environmental protection through the development of non-toxic and biodegradable substances, corrosion phenomena.

Prerequisites :
bachelor level in chemistry

Teaching language : english
Documents, website :

2A S4	MH24OP.ABC	**Practical Biotechnology (Practical Lab)** *Key words :* Practical work, biotechnology

Responsible : Corine MARIE Maitre de conférences
corinne.marie@chimieparistech.psl.eu

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* written report
	0 h	0 h	21 h		

Course outline :
Besides lectures on biological basic concepts, some specific practices in microbiology and bioprocess engineering, and some particular methods used in enzymology, molecular biology and histology are worthy of being directly experimented by students.
- Basic in microbial culture : medium preparation, sterilization, inoculation
- Kinetic study of microbial cultures : measurement of microbial biomass by different techniques, determination of carbon substrate and principal metabolite(s) concentrations at different sampling times.
Example of alcoholic fermentation and enzyme production by B. circulans.
- Labelling and observation of pro/eukaryotic cells.
- Bacterial production of a recombinant protein.
- Determination of Minimal Inhibitory Concentration (MIC)
- Study of enzymatic reactions.
- Determination of the aeration efficiency of a fermentor.

Learning objectives :
Regardless of their future professional position, the students must be aware of the constraints related to the manipulation, use and inactivation of living cells.
They must be able to take these constraints into account when managing projects dealing with biological issues.

Prerequisites :
bachelor level in chemistry

Teaching language : english
Documents, website :

MATERIALS OPTION

2A S4	MH24OP.PH3	**Physics III : Electronic Properties of Solids** *Key words :* band structure, electrical and optical properties, semiconductors, devices

Responsible : Laurent Binet Maître de Conférences, Chimie-ParisTech
laurent.binet@chimieparistech.psl.eu

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* written examination
	18 h	4.5 h	0 h		

Course outline :
The objective of this course is to describe the electronic structure of solids and the main properties and applications resulting from them, with an overview of current technological developments.
In the first part it introduces the basic concepts on the electronic band structures of solids and shows how these concepts explain the major families of properties, electrical, optical and chemical of solids.
In the second part, the course focuses on an important class of materials, semiconductors, and describes in detail the phenomena that occur in a p-n junction. The applications of such junctions are described, in particular solar cells, light-emitting diodes and laser diodes.

Learning objectives :
The student must be able to do:
- to define the characteristics of the two main models of electronic structure of solids and to know in which context to apply them,
- explain the main parameters that govern the electrical and optical properties of materials and the factors that have a positive or negative effect on these properties,
- interpret a band structure diagram of a solid and deduce its electrical and optical behaviour,
- describe in detail the electronic processes occurring in the main semiconductor devices and explain the factors controlling their performance
- to establish a structure-property relationship for a given application.

Prerequisites :
Quantum physics, quantum chemistry, crystallography, electromagnetism, BSc level

Teaching language : french
Documents, website : https://coursenligne.chimie-paristech.fr

2A S2	MH24OP.NOR	**Inorganic chemistry: from molecules to materials** *Key words :*

Responsible : Philippe Barboux Professeur
philippe.barboux@chimieparistech.psl.eu

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* multiple choice question 30 mn
	9 h	9 h	0 h		

Course outline :
The objective of this course is to give the rules of construction of all inorganic and mineral systems but also to show how much this inorganic chemistry is alive and has many applications in current problems (energy, environment, information storage, nanotechnologies...). An introduction to the industrial mineral chemistry industry completes the course (cements, glasses, aquatic chemistry, batteries). The theoretical part focuses on transition metal and lanthanide complexes and describes in particular their optical and magnetic properties.

Learning objectives :
At the end of the course, the student knows the periodic table and the trends of the different elements (ionization, complexation, orbital levels). He can describe a mineral system and choose between two simple approaches to describe inorganic complexes according to two ion binding or covalent binding models. He can explain the stability and reactivity of inorganic molecules based mainly on transition elements or elements of the p-block.

Prerequisites :
atomistics, chemical bonds, crystal field theory

Teaching language : french
Documents, website : handouts https://coursenligne.chimie-paristech.fr/enrol/index.php?id=308

2A S4	MH24OP.COR	**Corrosion (Electrochemical Stability of Materials)** *Key words :*

Responsible : Kevin Ogle Professeur
kevin.ogle@chimie-paristech.fr

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* Exam
	15 h	0 h	0 h		

Course outline :

Optimizing the functional lifetime of a material is a fundamental driving force for the development of new materials and in fact has been a preoccupation of our civilization from prehistory to the present day. This course will survey the mechanisms that determine the stability and reactivity of metallic materials in contact with diverse environments. We will evoke a number of critical questions: How can we predict the lifetime of materials in given applications and environments? How can we apply short term tests to predict the long term behavior of the materials? How can we incorporate anticorrosion concepts directly into the design of a new material?

We will seek a balanced presentation between fundamental physical chemistry useful for simulation of corrosion problems and the more intuitive approach often used in industry. Different viewpoints will be developed with an emphasis on the perspective of the developer of new, innovative materials.

The class will begin with a thorough review of the electrochemical theory of corrosion. We will then apply the theory to an interpretation of corrosion mechanisms focusing on the dynamics of the corroding system, reviewing in turn diverse forms of corrosion for different materials and environments. This will take us from the simplest case of uniform corrosion to complex material / environmental interactions leading to a high degree of localized damage. Special emphasis will be placed on the importance of passive film stability and metallurgical microstructure. The significance of corrosion resistance relative to other physical properties of the material will be emphasized.

Complex environments will also be considered such as occur during atmospheric corrosion when materials are exposed to rapidly changing and/or cyclic environments. We will also review examples of how anticorrosion concepts may be introduced into the design of new materials and assemblies of materials including passivity, inhibitors, and galvanic protection. As time permits we will also discuss coatings including metals, oxides and polymers and take a look at the mechanisms of corrosion at the metal/oxide /polymer interface for painted materials.

Learning objectives :

Recognize the various forms of aqueous corrosion.
Identify the corrosion risk for selected materials and environments.
Understand the fundamental chemical / electrochemical mechanisms of corrosion.
Apply the electrochemical theory of corrosion to identify mechanism and predict material lifetimes in a given environment.
Incorporate anti corrosion or optimized corrosion concepts into the criteria of material choice and design.

Prerequisites :

Electrochemistry, physical chemistry of solutions, introductory metallurgy

Teaching language : english
Documents, website :

2A S4	MH24OP.MOD	**Modeling** *Key words :* molecular modeling

Responsible : Carlo Adamo Professeur
carlo.adamo@chimie-paristech.fr

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* Written report
	4.5 h	0 h	9 h		

Course outline :
This module aims to train the engineering student in quantum and classical modelling of complex systems (molecules, solids, biomolecules) of industrial interest. The methods used to describe spectroscopic properties (IR, Raman, UV-Vis, NMR and EPR) and chemical reactivity are particularly targeted.
Particular interest is given to simulation methods currently used in the industrial and application field, and their use is illustrated by courses and seminars given by two external speakers from public or private institutions presenting their activity, in order to strengthen the link between modelling and the business world.
The training is based on alternating course and TP sessions, which allow students to put into practice the methods described in class using software of academic and industrial interest.

Learning objectives :
The student must be able to:
- choose the most suitable method according to the properties and system targeted
- interpret the results obtained and their limitations
- interact with modelling experts

Prerequisites :

Teaching language : french
Documents, website : handouts

2A S4	MH24OP.MM	**Surface properties and endurance of materials** *Key words :* surface characterization, nanostructure, reactivity

Responsible : Frédéric Wiame Maître de Conférences
frederic.wiame@chimieparistech.psl.eu

ECTS :	Course	Tutorials	Practical work	Mentoring	Evaluation method : written final exam
	19.5 h	3 h	0 h		

Course outline :
What is a surface? What are the specificities of surfaces compared to bulk? Why and how to study these surfaces? In this course we will try to answer these questions. The concepts of surface energy and stress will be introduced and their effects on the structure and properties of the surface will be studied. The initial stages of reactivity will be characterized in the framework of the adsorption theory.
The course will be illustrated by practical examples: growth of an oxide on an alloy, evolution of a metal interface in the presence of sulfur. These examples will highlight the different information that can be obtained using surface characterization techniques. Nanostructured surface fabrication methods will also be presented and the effects of nanostructuring on surface properties will be discussed.
After having seen the relationship microstructure-mechanical properties of metals, we propose here to go further by looking at the mechanisms that lead to the breaking of materials when exposed to mechanical loading or aging in a defined environment. This will allow us to address the issue related to the durability of metallic materials in conditions of use.

Learning objectives :
At the end of the course the student will be able:
- to identify and explain the main technological issues of the study of surfaces,
- to describe the fundamental differences between the properties of a surface and those of the bulk material,
- to determine the structure, characteristics and basic properties of a surface of given orientation,
- to describe the different adsorption mechanisms and give their main characteristics,
- to justify the usefulness of ultra-high vacuum and electronic spectroscopies for surface analysis and to identify the most appropriate techniques to answer a given problem,
- to highlight, by means of examples, the importance of the structure and the surface composition on the mechanisms and the kinetics of reactivity.

Prerequisites :

Teaching language : french
Documents, website : documents in english

2A S4	MH24OP.ELA	**inorganic materials elaboration** *Key words :* inorganic synthesis, ceramic, monocristalline synthesis ; thin films

Responsible : Giaume Maitre de Conférences
domitille.giaume@chimie-paristech.fr

ECTS :	*Course* 21 h	*Tutorials* 1.5 h	*Practical work* 0 h	*Mentoring*	*Evaluation method :* written final exam

Course outline :
This course presents the fundamentals of materials elaboration.
A first part presents the basics of monocristalline synthesis, starting from reflexion based on phase diagrams, nucleation-growth concepts and illustrations with various hot-temperature monocristalline routes. Such routes are predominant in the optic and photovoltaic domains. A second part deals with the physical and chemical principles underlying the solid-state densification and sintering of powders to obtain technical ceramics. Technical ceramics are a wide family of high-value materials for structural or functional applications (magnetic, optic, dielectric…). On the other hand, glass and glass-ceramics are materials prepared from the liquid state. Their elaboration is briefly presented at the end of this part. . The third part concerns the synthesis of small inorganic materials by low temperature routes. Basics of aqueous precipitation, sol-gel condensation, high-boiling solvent synthesis are thoroughly described, followed by the presentation of different methods for a chemist concerning the specific elaboration of thin or thick films.

Learning objectives :
At the end of this course, the students:
1) are aware of the various synthesis routes to elaborate inorganic materials;
2) Can evaluate the pros and cons of a specific synthesis route;
3) can chose the most adapted synthesis route for their study;
4) understand the mechanisms involved in the various synthesis routes;
5) propose consistent modification of the synthesis.

Prerequisites :

Teaching language : english
Documents, website : english documents
https://coursenligne.chimie-paristech.fr/course/index.php?categoryid=11

2A S4	MH24OP.MAT	**Practical work in materials science** *Key words :* materials science, preparation, characterization, project

Responsible : Pascal Loiseau Maître de Conférences
pascal.loiseau@chimieparistech.psl.eu

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* report
	0 h	0 h	30 h		

Course outline :
This practical work in materials science happens in second year. It is a 4 days project based on a topical issue that the students must appropriate. To adress this issue, the students must to mobilize many skills developed in first and second year at Chimie-ParisTech in order to propose relevant experimental protocols and characterization techniques.

Learning objectives :
From this practical work, the student will be able to:
- conceive and prepare a material addressing some desired properties
- apply relevant characterization techniques for a designed material
- propose some outlook aimed to optimize a material on the basis of structure-properties relationships

Prerequisites :
preparation of materials, characterization, properties of materials

Teaching language : english
Documents, website : scientific articles and technical documentation https://coursenligne.chimie-paristech.fr/course/view.php?id=298

PROCESS OPTION

2A S4	MH24OP.SP	**Process simulation** *Key words :* process simulation, economic analysis, material balance, energy balance

Responsible : Cédric Guyon Maître de conférences Chimie Paristech
cedric.guyon@chimieparistech.psl.eu

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* 30% written, 10% TP, 60% oral
	3 h	0 h	21 h		

Course outline :
The objective of this training is to simulate a real industrial process using commercial process simulation software (Aspen Hysys). It will involve choosing units (reactions, separation), optimizing the operating parameters and evaluating the unit's performance (production, selectivity, efficiency, etc.) according to the specifications set. Once these parameters have been established, students will have to evaluate the economic potential of the process studied (Aspen Icarus and bibliographic data).

Learning objectives :
Students who have completed this course will be able to:
-To carry out a material balance on a global process
-To simulate an industrial process on a large commercial software in static mode (Aspen plus, Aspen Hysys) in order to optimize the operating parameters of the process as well as possible
-To establish an economic balance of the process (energy costs, CO2 emissions, revenues, expenses, salary, installation costs, income taxes...)

Prerequisites :
Process simulation base acquired during the 2nd year practical work

Teaching language : french
Documents, website : english pdf https://coursenligne.chimie-paristech.fr/course/view.php?id=299

2A S4	MH24OP.COR	**Corrosion (Electrochemical Stability of Materials)** *Key words :*

Responsible : Kevin Ogle Professeur
kevin.ogle@chimie-paristech.fr

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* Exam
	15 h	0 h	0 h		

Course outline :

Optimizing the functional lifetime of a material is a fundamental driving force for the development of new materials and in fact has been a preoccupation of our civilization from prehistory to the present day. This course will survey the mechanisms that determine the stability and reactivity of metallic materials in contact with diverse environments. We will evoke a number of critical questions: How can we predict the lifetime of materials in given applications and environments? How can we apply short term tests to predict the long term behavior of the materials? How can we incorporate anticorrosion concepts directly into the design of a new material?
We will seek a balanced presentation between fundamental physical chemistry useful for simulation of corrosion problems and the more intuitive approach often used in industry. Different viewpoints will be developed with an emphasis on the perspective of the developer of new, innovative materials.
The class will begin with a thorough review of the electrochemical theory of corrosion. We will then apply the theory to an interpretation of corrosion mechanisms focusing on the dynamics of the corroding system, reviewing in turn diverse forms of corrosion for different materials and environments. This will take us from the simplest case of uniform corrosion to complex material / environmental interactions leading to a high degree of localized damage. Special emphasis will be placed on the importance of passive film stability and metallurgical microstructure. The significance of corrosion resistance relative to other physical properties of the material will be emphasized.
Complex environments will also be considered such as occur during atmospheric corrosion when materials are exposed to rapidly changing and/or cyclic environments. We will also review examples of how anticorrosion concepts may be introduced into the design of new materials and assemblies of materials including passivity, inhibitors, and galvanic protection. As time permits we will also discuss coatings including metals, oxides and polymers and take a look at the mechanisms of corrosion at the metal/oxide /polymer interface for painted materials.

Learning objectives :

Recognize the various forms of aqueous corrosion.
Identify the corrosion risk for selected materials and environments.
Understand the fundamental chemical / electrochemical mechanisms of corrosion.
Apply the electrochemical theory of corrosion to identify mechanism and predict material lifetimes in a given environment.
Incorporate anti corrosion or optimized corrosion concepts into the criteria of material choice and design.

Prerequisites :

Electrochemistry, physical chemistry of solutions, introductory metallurgy

Teaching language : english
Documents, website :

2A S4	MH24OP.MOD	**Modeling** *Key words :* molecular modeling

Responsible : Carlo Adamo Professeur
carlo.adamo@chimie-paristech.fr

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* Written report
	4.5 h	0 h	9 h		

Course outline :
This module aims to train the engineering student in quantum and classical modelling of complex systems (molecules, solids, biomolecules) of industrial interest. The methods used to describe spectroscopic properties (IR, Raman, UV-Vis, NMR and EPR) and chemical reactivity are particularly targeted.
Particular interest is given to simulation methods currently used in the industrial and application field, and their use is illustrated by courses and seminars given by two external speakers from public or private institutions presenting their activity, in order to strengthen the link between modelling and the business world.
The training is based on alternating course and TP sessions, which allow students to put into practice the methods described in class using software of academic and industrial interest.

Learning objectives :
The student must be able to:
- choose the most suitable method according to the properties and system targeted
- interpret the results obtained and their limitations
- interact with modelling experts

Prerequisites :

Teaching language : french
Documents, website : handouts

2A S2	MH24OP.NOR	**Inorganic chemistry: from molecules to materials** *Key words :*

Responsible : Philippe Barboux Professeur
philippe.barboux@chimieparistech.psl.eu

ECTS :	*Course* 9 h	*Tutorials* 9 h	*Practical work* 0 h	*Mentoring*	*Evaluation method :* multiple choice question 30 mn

Course outline :
The objective of this course is to give the rules of construction of all inorganic and mineral systems but also to show how much this inorganic chemistry is alive and has many applications in current problems (energy, environment, information storage, nanotechnologies...). An introduction to the industrial mineral chemistry industry completes the course (cements, glasses, aquatic chemistry, batteries). The theoretical part focuses on transition metal and lanthanide complexes and describes in particular their optical and magnetic properties.

Learning objectives :
At the end of the course, the student knows the periodic table and the trends of the different elements (ionization, complexation, orbital levels). He can describe a mineral system and choose between two simple approaches to describe inorganic complexes according to two ion binding or covalent binding models. He can explain the stability and reactivity of inorganic molecules based mainly on transition elements or elements of the p-block.

Prerequisites :
atomistics, chemical bonds, crystal field theory

Teaching language : french
Documents, website : handouts https://coursenligne.chimie-paristech.fr/enrol/index.php?id=308

2A S4	MH24OP.OCP	**Optimization and process control** *Key words :* design of experiments, linear regression, regulation, PID controller

Responsible : Jerome PULPYTEL Maître de Conférences Sorbonne Université
jerome.pulpytel@sorbonne-universite.fr

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* written exam (100%)
	6 h	18 h	0 h		

Course outline :
This course is divided in two parts. The first concern the design of experiments. This statistical and mathematical method allows to reduce the number of experiments and to optimize multifactorial processes. The students will practice "classical" design such as full factorial, fractional factorial and central composite design, as well as statistics to interpret the results.
The second part is dedicated to the methods used to control processes. Regulation is indeed a key part to ensure the quality and safety of industrial processes. Open loop and closed loop feedback control will be discussed, and especially the PID (proportional-integral-derivative) controller developed in the 1920's for the manufacturing industry and which are nowadays used universally for automatic control.
Practical exercise will be carried out with Matlab and Nemrodw.

Learning objectives :
Students will be able to define an experimental design, to choose the best strategy to optimize processes, to calculate linear regression model and interpret the results using statistical tools. They will know how to identify a regulation method, calculate and set the controlling parameters. They will also explain the different methods to measure the fundamentals physical parameters in a chemical process (flow, temperature).

Prerequisites :
none

Teaching language : french
Documents, website : handouts

2A S4	MH24OP.FLC	**Flow chemistry** *Key words :* flow chemistry, process intensification, millireactors

Responsible : Stéphanie Ognier MCF
stephanie.ognier@chimieparistech.psl.eu

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* written examination (70%) and practical work (30%)
	15 h	3 h	3 h		

Course outline :
Process intensification is part of an effort to improve the productivity and selectivity of chemical reactions, in particular through the use of micro / micro-structured reactors, in-situ reaction / separation coupling and the use of alternative energy sources (photochemistry, ultrasound etc ...). The teaching will include a first theoretical part whose objective is to show how the intensification of transfers within a chemical reactor influences its performance. In this first part, concrete examples will be analyzed in class, in tutorials and practical work. The second part will be more descriptive and involve teachers and researchers from disciplines other than process engineering (materials, molecular chemistry). They will share their experiences as users of the new intensified technologies.

Learning objectives :
The objective of this teaching unit is to train students in the field of process intensification. At the end of the training, students must be able to:
• Understand the context of intensification
• Describe the fundamentals of material, heat and momentum transfer, especially in small channels
• Analyze referenced industrial cases and developments in chemical engineering
• Analyze academic examples of flow chemistry in the fields of molecular synthesis and material synthesis
• Propose relevant intensification solutions in the case of a given process

Prerequisites :
fundamentals in fluid hydrodynamics, mass and heat transfer, reaction engineering

Teaching language : french
Documents, website : course transparencies, statements of tutorials and practical work

2A S4	MH24OP.PRO	**Experimental training for flow chemistry** *Key words :* flow chemistry, micro-reactor, reaction engineering

Responsible : Cédric Guyon Maître de conférences Chimie Paristech
Cedric.guyon@chimieparistech.psl.eu

ECTS :	*Course* 0 h	*Tutorials* 0 h	*Practical work* 30 h	*Mentoring*	*Evaluation method :* 100% TP

Course outline :
This experimental training is offered as part of the Flow Chemistry option in Chemical Engineering for 2nd year students at school. It takes the form of a practical work course
The teacher will first introduce the different miniaturized reactors and the control system (flow control, temperature control, etc.) for these reactors. Then, the students will realize a flow chemistry set-up with glass micro-reactors, for a parallel reaction system. The concepts of "residence time", "mixing time" will be presented during the course, and the advantages and drawbacks of the miniaturized reactor will also be discussed.

Learning objectives :
The objective of this teaching unit is to give students practical skills in flow chemistry.
At the end of the course, students will be able to:
- Carry out a continuous flow chemistry set-up
- Characterize the mixing/reaction time in a miniaturized reactor
- Establish the material/energy balances in a reactive system
- Compare different reactors (miniaturized reactor and batch reactor) for a parallel reaction system
- Discuss the advantages and/or drawbacks of the flow chemistry system compared to conventional reactors
- Choose a suitable reactor for a given process

Prerequisites :
Chemical Engineering 1&2 year

Teaching language : french
Documents, website : handouts

MOLECULAR CHEMISTRY OPTION

2A S4	MH24OP.HC	**Heteroelements and applied catalysis** *Key words :* catalysis, transition metals, coupling reactions, heteroelements

Responsible : Phannarath Phansavath
phannarath.phansavath@chimieparistech.psl.eu

ECTS :	*Course* 15 h	*Tutorials* 7.5 h	*Practical work* 0 h	*Mentoring*	*Evaluation method :* Final written exam (1.5 h)

Course outline :
The Chemistry of heteroelements course aims to present the different methods of preparation of phosphorus, sulfur and silicon reagents as well as the main transformations carried out with these compounds, with applications in total synthesis. The objective of the Applied Catalysis course is to provide the basis for organometallic chemistry involving transition metals (palladium, rhodium and ruthenium) as a tool for the development of synthetic processes. Coupling reactions and other major applications in homogeneous catalysis are presented with emphasis on reaction mechanisms, but also on applications both at the industrial level and in the synthesis of natural molecules or molecules of biological interest.

Learning objectives :
At the end of the course, the student will be able to master the methods used to carry out the main transformations carried out with phosphorus, sulphur or silicon derivatives, and will be able to explain the corresponding reaction mechanisms. He will be able to use the appropriate organometallic complexes to carry out the main coupling reactions and other major reactions used in homogeneous catalysis.

Prerequisites :
Good knowledge of the basic reactions of organic chemistry and good understanding of classical reaction mechanisms

Teaching language : french
Documents, website :

2A S4	MH24OP.CBI	**Bioinorganic Chemistry** *Key words :* Medicinal Inorganic Chemistry, Bioorganometallic Chemistry, Bioinorganic Chemistry, Inorganic Chemical Biology.

Responsible : Gilles Gasser
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ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* Written Exam.
	15 h	0 h	0 h		

Course outline :
Nature utilizes metal ions and metal complexes to undertake several crucial processes. In fact, a human being requires about 25 elements to have a healthy life, half of them being metals! The chemical study of metals in biology is referred as bioinorganic chemistry. This area of research encompasses the study of metallo-enzymes (i.e. vitamin B12) or biological processes such as respiration. In this course, a general overview of the role of metals in biology will be presented. It is also planned to outline to role that metal complexes can play to understand biological processes.

Learning objectives :
The course will be divided into two main sections. In the first section, the role of metal ions in a few key metalloproteins and biological processes will be explained. The second section will focus on the use of metal complexes to detect specific organelles/biomolecules, or a discussion to understand/modify biological processes. A large emphasis will be placed on experiments, which have been carried out in living cells or organisms.

Prerequisites :
This course requires basic knowledge of inorganic chemistry and biochemistry.

Teaching language : english
Documents, website :

2A S4	MH24OP.MOM	**Molecular Modeling** *Key words :*

Responsible : Carlo Adamo Professeur
carlo.adamo@chimie-paristech.fr

ECTS :	*Course*	*Tutorials*	*Practical work*	*Mentoring*	*Evaluation method :* Written report
	4.5 h	0 h	9 h		

Course outline :
This module aims to train the engineering student in quantum and classical modelling of complex systems (molecules, solids, biomolecules) of industrial interest. The methods used to describe spectroscopic properties (IR, Raman, UV-Vis, NMR and EPR) and chemical reactivity are particularly targeted.
Particular interest is given to simulation methods currently used in the industrial and application field, and their use is illustrated by courses and seminars given by two external speakers from public or private institutions presenting their activity, in order to strengthen the link between modelling and the business world.
The training is based on alternating course and TP sessions, which allow students to put into practice the methods described in class using software of academic and industrial interest.

Learning objectives :
The student must be able to:
- choose the most suitable method according to the properties and system targeted
- interpret the results obtained and their limitations
- interact with modelling experts

Prerequisites :

Teaching language : french
Documents, website : handouts

2A S4	MH24OP.COM	**Organometallic Chemistry** *Key words :*

Responsible : THOMAS Christophe Professeur
christophe.thomas@chimie-paristech.fr

ECTS :	*Course* 7.5 h	*Tutorials* 7.5 h	*Practical work* 0 h	*Mentoring*	*Evaluation method :* Written examination

Course outline :
This course describes the fundamental reactions of transition metal complexes and some (industrially relevant) catalytic cycles. This course provides an introduction to catalysis as a tool for the development of clean and energy efficient synthesis processes.

Learning objectives :
The first objective of this course is to rationalize the reactivity of catalytically generated molecules and intermediates. The second objective is to develop a catalytic cycle in organometallic chemistry and to determine the appropriate analytical methods for the mechanistic study of a catalytic reaction by transition metal compounds.

Prerequisites :

Teaching language :
Documents, website :

2A S4	MH24OP.SAR	**Asymmetric Synthesis and Retrosynthesis** *Key words :*

Responsible : SylvainDarses
sylvain.darses@chimie-paristech.fr

ECTS :	*Course* 15 h	*Tutorials* 7.5 h	*Practical work* 0 h	*Mentoring*	*Evaluation method :* Written exam

Course outline :
Principles and tools in retrosynthesis and organic synthesis. Generalities, examples of disconnections and reconnections. Strategies: convergence, selectivities, cascade reactions, synthetic equivalents, polarity inversion. Activation methods, protection/deprotection of the main functional groups. The control of chirality. Resolution (chemical, enzymatic, chromatographic). The use of chirons. The use of chiral auxiliaries. Asymmetric catalysis.
Selected applications in the pharmaceutical and agrochemical industry will document this course.

Learning objectives :
To recognize the importance of chirality in organic synthesis and for the bioactivity of molecules. To analyze and understand the elements of stereochemistry of the reactions. To know the main asymmetric catalytic or non-catalytic synthesis methods used in the pharmaceutical or agrochemical industry. To recognize and analyze key milestones and important motives in multi-step asymmetric syntheses. To plan a viable synthetic strategy for a target molecule by performing consistent disconnections, and proposing a detailed synthetic approach.

Prerequisites :
Basic stereochemistry, bases of kinetics and thermodynamics, basic organic synthesis, organometallic chemistry.

Teaching language : french
Documents, website :

2A S4	MH24OP.MOL	**Experimental training in molecular chemistry** *Key words :*

Responsible : Sylvain Darses
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ECTS :	*Course* 0 h	*Tutorials* 0 h	*Practical work* 60 h	*Mentoring*	*Evaluation method :* Laboratory work: theoretical and practical understanding, techniques, productivity, behavioral, written report.

Course outline :
Preparation of experimental design: bibliographic research, choice of method, reaction mechanism, assessment, security elements related to manipulation. Preparation and maintenance of a laboratory notebook. Good laboratory practices and health and safety rules. Starating and performing the synthesis steps. Isolation and purifications. Chemical, physicochemical and structural characterizations. Writing a report.

Learning objectives :
The aim of the experimental training in molecular chemistry is to bring the student, through an individual work or in pairs, to an improvement of his theoretical and practical knowledge in molecular chemistry. The module will consist of a short-project (a few reaction steps), related to the teaching module for which the student is responsible in interaction with a supervising teacher. The student will have to provide a report on the work done. This form of education aims to give the student a certain form of autonomy and responsibility in his work in the laboratory, a work closely related to that of the industry.

Prerequisites :
Molecular chemistry courses, prior experience in molecular chemistry laboratory.

Teaching language : french
Documents, website :

BIOTECHNOLOGIES OPTION (ESPCI)

Option occurring at the ESPCI engineering school

Presentation:
The 3rd year of the ESPCI Biotechnology course offers a fully interdisciplinary course, combining basic knowledge (finance, microfluidics, statistics, etc.), specific courses (molecular biotechnology, synthetic biology and systems), and a panel of options allowing an exhaustive exploration of the different interfaces with biology..: Physics (Mechanics of Life, Biophysics, Complex Waves, Medical Imaging), Physico-chemistry (Colloids and Biomolecules), analytical chemistry (Bioanalytics, complex samples and miniaturization) and chemistry (Organic Chemistry and Heterocyclic Chemistry, Inorganic Chemistry). This course provides the appropriate luggage to consider all the interfaces of Biology with other sciences, whether for engineering or research.

Program:
MANDATORY COURSES:
- English 21h
- Fundamentals of Finance 14h
- Microfluidics 17h
- Statistics10h
- Statistics and modelling 12h
- Chemometrics 12h
- Big Data 14h
- Synthetic Biology and Systems 36h
- Colloids and Biomolecules 11h
- Molecular Biotechnology 17h
- Biophysics 14h
- Life Mechanics 15h
- Bioanalysis, complex samples and miniaturization 12h

OPTIONS:
- Soft Matter and Development - Rheology 28h
- Measurement Physics 13h (+18h TP)
- Organic Chemistry and Heterocyclic Chemistry 24h
- Medical Imaging 18h
- Complex Waves 12h
- Inorganic Chemistry 12h

2A S4	MH24ES.SI	**Technical 2A internship in a laboratory and/or company** *Key words :* technical internship, experimentation, discovery of the professional environment

Responsible : Christophe Thomas, Maria Malheiro Professeur
christophe.thomas@chimieparistech.psl.eu ; maria.malheiro@chimieparistech.psl.eu

ECTS :	*Course* h	*Tutorials* h	*Practical work* h	*Mentoring*	*Evaluation method :* report 50% Oral presentation 50%

Course outline :
For five months, the student performs a practical internship in a company or research laboratory during which he applies the theoretical, scientific and technical knowledge acquired during his school years in the domain of his specialty. As part of a team, he or she carries out a mission under the responsibility of a supervisor.
For engineering students only: At least one of the two second or third year internships must be completed in a company. At least one long-term international experience (at least 5 months) is also required, either in the form of one of the two internships 2A or 3A or a mobility of at least one semester to follow theoretical courses abroad.

Learning objectives :
The student must master the methods and tools adapted to his mission by understanding the theoretical bases of their operation.
It must develop an experimental approach by collecting data with scientific rigour. He must be able to analyse his results and synthesize them. He must learn to account for and expose his work through a written report and an oral statement.
He must adapt to the life of his company by understanding its strategy. He must respect the constraints and requirements of his company by integrating into a team and adapting to the human relations of his workplace.

Prerequisites :
scientific and technical knowledge at master level

Teaching language : french or english as apropriate
Documents, website :

ADDITIONAL COURSES

• *ATHENS Week (semester 3)*

Presentation

This week takes place in the European Grandes Ecoles and universities which constitute the ATHENS network, it allows you to choose courses which you do not follow in your courses. Several of these courses are given by professors from the academic sector and experts from the industrial world.

Responsible: Pascal Bigey pascal.bigey@chimieparistech.psl.eu

ECTS credits: 2

• *PSL Week (semester 4)*

Objectives : Acquisition of skills and knowledge complementary to their field of specialization

- mobility of students between PSL schools
- to encourage interaction between engineering students in PSL schools

Program : During the PSL week, students follow one week of classes at Chimie ParisTech or in another PSL establishment: ESPCI, la Femis or Mines Paristech. This week of courses is an opening week where engineering students can study a field related to chemistry, in fundamental or applied sciences, but also in project management, such as Drugs and pathologies, Technologies and Innovation, History of science, Design of innovative products, The value of water, Processes and microfluidics... The form, content and assessment of each week depend on the course week chosen.

ECTS credits: 2

• *Additionnal foreign language(s):*

French as Foreign Language

Description : Lectures focus on:

1)the ability to follow and participate in science courses: oral and written comprehension, written and oral production

2) communication with French students and social life in France, in order to facilitate integration into the School and in France

Cultural activities (museum visits) may be organised to help student learning French

Objective : To get at least B2 level in French or C1

Knowledge : Depends on the level

Skills : Understanding of the everyday language through film, radio or television broadcasts

Improvement of writing skills through writing and rewriting workshops.

Ability to listen and express oneself is encouraged through exercises to summarize audio-visual programmes, and debates, the presentation of cultural "PowerPoints" given to students in small groups - 2 groups (B1 and B2) – 2h per week per semester

Spanish
German
Chinese
Japanese
Russian
Portuguese
Italian
Arabic

Responsible: Daria Moreau daria.moreau@chimieparistech.psl.eu

ECTS credits: 1

• *Sport* ECTS credits: 1