Integrative Chemistry and Innovation
Master degree

Course syllabus - M1 level

2021-2022

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Basic science courses	
Introductory Mathematics and Physics	3
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Innovative Transdisciplinary Project	2
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SEMESTER 1

Basic science courses

C&I M1	S1	**Course Title: Introductory Mathematics and Physics** *Keywords: linear algebra, Hamiltonian, group theory, crystallography, applied statistics*

Instructor(s), Coordinator	Name(s) and e-mails : F. Labat (frederic.labat@chimieparistech.psl.eu), L. Binet (laurent.binet@chimieparistech.psl.eu), P. Loiseau (pascal.loiseau@chimieparistech.psl.eu), J. Vial (Jerome.Vial@espci.fr)

ECTS : 3	*Total hours* : 30 h	*rating: final exam: written (100%)*

Description

This module introduces the main concepts in mathematics and physics useful to follow the Chemistry & Innovation track of the Graduate Program in Chemistry.

The training is based on three main courses: applied statistics (9h), mathematics (6h) and physics (15h), which are each presented with illustrating examples and exercises in class.

The main concepts covered are: applied statistics, linear algebra, Hamiltonian and Fourier transform, along with quantum physics, group theory, symmetry, crystallography and diffraction.

Learning goals

The student should be able to:

- understand the notions of random variable, distribution, estimation, hypothesis formulation and testing
- know the basic concepts of quantum physics and chemistry, such as linear algebra, Hamiltonian, eigenspace, hermiticity and Fourier transform
- understand the main concepts of quantum physics, group theory, symmetry, crystallography and diffraction, along with their connections.

Pre-requisites

None

C&I M1	S1	**Course Title: Molecular Design and Synthetic Tools - Basics** **Synthetic Molecular Chemistry and Biochemistry** *Keywords: C-C bond formation, asymmetric synthesis, rearrangements, pericyclic reactions, organometallic catalysis, coordination chemistry, biochemistry*
Instructor(s), Coordinator		Guillaume Lefèvre (guillaume.lefevre@chimieparistech psl.eu) Yann Verdier (yann.verdier@espci.psl.eu)

ECTS : 3	*Total hours : 24h*	*rating: final written exam*

Description

This course will be divided into 3 units:

a) Basics in organic chemistry

Contents: 4 courses. (i) classical synthetic tools for C-C bond formations, reactivity of usual functional groups (carbonyls, iminiums, enamines, Mannich reaction and related transformations, Evans aldol reaction); (ii) asymmetric / diastereoselective synthesis involving main-group reagents; (iii) rearrangements and transpositions; (iv) pericyclic reactions.

b) Basics in organometallic chemistry

Contents: elementary steps in organometallic chemistry, reactivity of transition-metal complexes, electron counting in complexes, usual C-C bond formation or C=C hydrogenation catalytic cycles (hydrogenation, metathesis, cross-coupling, extension to industrial synthesis of fine chemicals (e.g.: L-DOPA) or to high-scale processes (eg: acetic acid in Cativa / Monsanto processes)).

c) Basics in biochemistry

Contents: the chemistry of life; 50 molecules to know: Nucleic acid, Amino acids and proteins, Carbohydrates & Lipids; DNA and the genetic code; RNA synthesis, Protein synthesis ; Enzymes.

Learning goals

The student should be able to:

- Give the mechanism of multistep transformations of complex targets involving carbonyls as well as carboxylic acids and derivatives, interpret the diastereoselectivity of transformations based on simple models, give the mechanism of multistep rearrangements and various pericyclic reactions, demonstrate that pericyclic reactions are allowed using adequate selection rules.
- Give a catalytic cycle for simple transformations in organometallic catalysis, and analyze the evolution of the oxidation state / electron number of the intermediates involved, as well as interpret the electronic effect of several ligands on the catalytic efficiency in some simple cases.
- Describe the structure and function of the major classes of biomolecules.
- Explain the mechanisms of DNA, RNA and protein synthesis and regulation.

Pre-requisites

Good knowledge of reactivity of classic functional groups. No pre-requisite for the organometallic and biochemistry courses.

<table>
<tr><td>C&I M1</td><td>S1</td><td colspan="2">Course Title: Analytical and Physical Chemistry – Basics
Keywords: solution chemistry ; physical chemistry and interfaces, separation sciences, electrochemistry, molecular spectroscopy</td></tr>
<tr><td colspan="2">Instructor(s), Coordinator</td><td colspan="2">Name(s) and e-mails
Fethi Bedioui (fethi.bedioui@chimieparistech.psl.eu), Jean-François Hochepied, Fanny d'Orlyé, Fabien Ferrage</td></tr>
<tr><td colspan="2">ECTS : 3</td><td>Total hours : 24</td><td>rating: final written exam (75%), intermediate reports (25%)</td></tr>
</table>

Description

The course is aimed at arming the student with fundamental concepts in solution thermodynamics and molecular spectroscopies enabling to understand and address experimental questions on how to characterize, analyze, separate molecular components in solutions or complex mixtures

(i) **Solution chemistry**: Brønsted & Lewis acids & bases; complexation; solubility & precipitation
(ii) **Physical chemistry and interface**: (a) focus on gases, ionic solutions and binary mixtures, emphasizing the notion of ideality and non-ideality and use of valid models for real behaviours (Van der Waals, Debye-Huckel models, regular solutions for example); (b) basics laws such as Laplace, Jurin, Kelvin, Young, Gibbs will be presented to describe the presence of bubbles, droplets, surfactants etc…. Finally, the Gibbs adsorption model will be introduced focusing on surfactant effect
(iii) **Separation Sciences**: basic principles of mechanical separation processes (such as sedimentation, decantation, centrifugation, membrane processes …) and diffusion separation processes (such as extraction, crystallization, chromatography …) and introducing the notions of sample pretreatment and multi-step analysis for the development of analytical strategies
(iv) **Electrochemistry**: fundamental principles of electrochemistry, in particular microelectrolysis and the current-potential characteristics i=f(E) to elaborate a basis for the approach in analysis. An overview of the effect of the size of the electrode and the chemical medium on i=f(E) curves will also presented
(v) **Molecular spectroscopy**: NMR: structure of NMR 1D spectra (energy levels. time-independent Schrödinger equation; angular momentum operators; nuclear spin Hamiltonian; energy levels and transition energies for a system of two coupled spins; principles of a 1D NMR experiment (the vector model. Nuclear Magnetization, Bloch Equations; radiofrequency pulses; Fourier transform). Optical spectroscopies: basics of absorption and emission, effects of structure and environment, lifetime of excited electronic states; quantum yield and non-radiative transitions; inhibition of fluorescence

Learning goals

The student should be able to:
- Predict acid-base, complexation or precipitation reactions in a system knowing its composition,
-Take into account non-ideality to describe the properties of mixtures (either in gas, solution, binary mixtures,..) and adapt the laws of thermodynamics to systems where the interface plays a predominant role,
- understand the fundamental aspects of electrochemistry, how to integrate the effect of the chemical medium (acidity, complexation, precipitation) and the size and shape of the electrode in the establishment and plot of i = f (E) curves,
- know the principal forces and interactions that control the performances of each separation method and evaluate these methods in terms of recovery rate, separation selectivity, concentration factor,
- Understand the physical principles of NMR and optical spectroscopies.
- Understand how a simple NMR experiment is performed.
- Describe the structure of these simple spectra.

Pre-requisites

Basics in thermochemistry, inorganic chemistry, organic chemistry, redox chemistry.
Mathematical basics applied to thermodynamics (integration, derivatives, exact total differentials, cross derivatives, differential equations)
Basics of quantum physics and chemistry (Schrödinger equation, energy levels). Descriptive 1D spectroscopy (1D proton NMR, absorption spectra in optical spectroscopies).

C&I M1	S1	**Course Title: Theoretical Chemistry and Modelling – Basics** **Fundamentals of Theoretical Chemistry** *Keywords: electronic structure, statistical mechanics, quantum chemistry, thermodynamics*
Instructor(s), Coordinator		Name(s) and e-mails Ilaria Ciofini, François-Xavier Coudert
ECTS : 3	*Total hours : 24*	*rating: final written exam (67%), intermediate reports (33%)*

Description

Part 1: Basic Electronic Structure Theory

The knowledge of the electronic structure of molecules and extended systems allows for the understanding of their reactivity and properties. Here we will provide a general introduction to the methods and concepts encountered when aiming at describing the electronic structure of single to multi electronic atoms and molecules.
After the introduction of Schrödinger equation and of the common approximations applied to solve it, we will be detailed the Hartree Fock method and define the concept of electronic correlation. Examples on how reactivity can be linked to frontier orbitals analysis will also be given in the case of molecular systems.

Part 2 : Fundamentals of Statistical Mechanics

Statistical mechanics is one of the pillars of modern physics, linking the laws of physics at the microscopic scale, at the quantum (Schrödinger's equation) or classical level (Newton's laws), with the properties of matter and its macroscopic behavior (the laws of thermodynamics). We introduce the fundamentals of statistical mechanics, and introduce the concepts of temperature, work, heat, and entropy, the postulates of statistical mechanics, the notion of statistical ensembles and their use in the calculation of average quantities. We will cover simple models that are widely found throughout physics and chemistry: harmonic oscillator, ideal and nonideal gases, phase transitions, mean field approximations.

Learning goals

The student should be able to:

- understand the meaning of the Schrödinger equation
- know the common approximations used to solve Schrödinger
- describe a multi-electronic atomic or molecular system using the Hartree-Fock method
- define the concept of electron correlation
- rationalize the reactivity of a molecular system on the basis of frontier orbitals analysis
- know the difference between classical and quantum models
- calculate the partition function of a given system
- determine the thermodynamic properties from the partition functions
- apply a mean field approximation
- use equations of state and phase diagrams

Pre-requisites

BSc level in physical chemistry, quantum chemistry, thermodynamics

C&I M1	S1	**Course Title: Smart Materials Chemistry – Basics** **Introduction to inorganic and soft materials** *Keywords: Inorganic and soft matter, hybrids materials, synthesis and characterization*
Instructor(s), Coordinator		Bruno Viana (bruno.viana@chimieparistech.psl.eu) 12h, Michel Cloitre (michel.cloitre@espci.fr) 12h
ECTS : 3	*Total hours : 24h*	*rating: final exam (written), intermediate exams, assignments, reports*

Description

This course aims at giving the rules of construction of all inorganic, organic and hybrid systems but also to show their richness and their applications in current problems (such as energy, environment, photonics, nanotechnologies …).

The first part will be an "Introduction to Inorganic Materials" presenting at first basics of the solidification, including symmetry properties, intrinsic and extrinsic defects in solids, thermodynamics stability. Focus materials will be ionic solids, ionocovalent and ionometallic solids. Basic concepts on the electronic band structures and structure-properties relationships will be envisioned. We will present the fundamental aspects in the synthesis of inorganic materials, including phase diagrams, concepts of growth of inorganic materials from nanocrystals to large size materials and their characterization methods.
Nanoparticles synthesis and functionalization will be presented. Materials synthesis using "Chimie douce", i.e. synthesis in solution at relatively low temperature of oxides (sol gel chemistry), organic-inorganic hybrids, molecular compounds, as well as carbon-based solids (graphene…) will be introduced.
Soft Matter encompasses very different materials that share in common weak cohesive forces and a great sensitivity to the environment: polymers, colloids, surfactants, liquid crystals. Behind this apparent diversity, they exhibit common features that can be understood in terms of unifying concepts borrowed from thermodynamic and statistical physics: entropy, enthalpy, phase separation, molecular forces.
The course "Introduction to Soft Matter" will provide the student with a global approach connecting molecular design, synthetic chemistry, mesoscopic and macroscopic structure, material properties, and applications. Selected topics will include an introduction to polymers in bulk and solutions, colloids, and self-assembled systems made of block copolymers, surfactants, and liquid crystals. We will show how transport, flow, mechanical, and optical properties are exploited in advanced functional materials and processes.

Learning goals

At the end of this course, the student will be able to acquire the following knowledge and skills:

- Appropriate the description of the main structural types characterizing solids.
- Be able to distinguish the different types of defects in a solid and be aware of the mechanism of the formation of defects in a solids and the remarkable properties associated with these defects.
- Understood the different existing synthesis routes for the development of inorganic materials. Can assess the pros and cons of these pathways.
- Mobilize a multidisciplinary background in chemistry and physics to rationalize important material behaviors in Soft Matter (i.e. solubility versus phase separation).
- Connect macroscopic behavior to microscopic phenomena (competition between entropy and enthalpy as a driven force for self-assembly)
- Draw analogies between different soft materials.
- Be ready to tackle more complex problems like the design of materials with tailored properties

Pre-requisites

Thermodynamics, Chemical bonding, Group theory,

SEMESTER 1

Advanced science courses

C&I M1	S1	**Course Title: Molecular Design and Synthetic Tools – Advanced Synthetic tools for health sciences** *Keywords: Retrosynthesis, Total Synthesis, Atom- and Step-Economy, transition-metal catalysis, mechanisms, ligand effects, non-noble metals*

Instructor(s), Coordinator	Kevin Cariou (kevin.cariou@chimieparistech.psl.eu), Guillaume Lefèvre (guillaume.lefevre@chimieparistech.psl.eu)

ECTS	*Total hours: 24h*	*rating: final written exam*

Description

This course advanced course is divided into two units:

a) Retrosynthetic analysis and total synthesis of bioactive compounds (12 h, K. Cariou)
This course will introduce the principles of retrosynthetic analysis and their applications for the design of synthetic routes. Recent examples of syntheses of bioactive molecules (whether natural products or manufactured drugs) will serve as illustrations and a particular emphasis will be placed on atom- and step-economic synthetic strategies.
The course will be divided between classes and practical exercises that will take the form of team projects.

b) Advanced organometallic chemistry (12 h, G. Lefèvre)
This course follows the “basics in organometallic chemistry” course. Classic transition-metal-catalyzed processes (in particular cross-coupling, C-H activation, formation of C-C bonds involving radicals) will be discussed from a mechanistic standpoint (kinetics data, role of the ligand in the promotion of the elementary steps of the catalytic cycle). An overview of the state-of-the art in non-noble metal catalysis (e.g. with 3^{rd}-row metal catalysts) will also be given.

Learning goals
The student should be able to:

- do the retrosynthetic analysis of a given molecule
- propose the key synthetic steps
- devise an efficient synthetic strategy
- solve a synthetic problem through teamwork
- extract the key data from a scientific publication
- rationalize the choice of a catalytic system (ligand, metal, conditions) for a given goal
- suggest a plausible catalytic cycle taking into account of experimental data

C&I M1	S1	**Course Title: Analytical and Physical Chemistry – Advanced** **Physical chemistry of detection, probing and imaging** *Keywords: sample treatment, separation, detection, trace or even ultra-trace analysis, process miniaturization, mesoscale and supramolecular characterizations and imaging*

Instructor(s), Coordinator	Name(s) and e-mails Laure Trapiella (laura.trapiella@chimieparistech.psl.eu), Fethi Bedioui, Christophe Tribet, Fanny d'Orlyé, Anne Varenne, Bich-Thuy Doan

ECTS : 3	*Total hours : 24h*	*rating: rating: final written exam (67%), intermediate reports (33%)*

Description

This course has two parts and it is aimed at presenting a journey of discovery of up-to-date techniques and design of molecular probes used to investigate molecular compositions of samples, and/or spatial organization and dynamics of molecules or assemblies. The objective is to become familiar with most common analytical methods, types of spectroscopy, and imaging practices. To complement fundamental presentations of the methods, a hands-on understanding will be provided by visiting experts in their laboratories.

(i) **Analytical physico-chemistry for environmental analysis**: the course will focus on detection techniques (i.e. spectroscopic, electrochemical) capable to reach very low detection limits of pollutants and the need for the development of portable, rapid, reliable and in-situ analysis, thus the need of the miniaturization, will be presented (Laura Trapiella; 6h)
(ii) **Analytical physico-chemistry for biotechnology and clinical diagnostics:** notion of biomarkers and sample matrix effects will be presented. Then the different kinds of biorecognition events and associated bioassay formats will be introduced. Also considering the whole analytical process the main processes on sample treatment, separation techniques and coupling with performant detection methods (i.e. spectroscopic and electrochemical) will be illustrated. Finally, the concept of method/test validation will be afforded in the view of the development of new analytical strategies that can arrive to the end-users (Laura Trapiella; 6h).
(iii) **Radiation-based analysis, from spectroscopy to imaging (part I):** basics of the chemical probes and probing methods at the molecular level will be presented in MRI, EPR, optical mono (IR, UV-Vis)/bi-photon fluorescence to characterize the structure and understand the properties of probes. Advanced applications in cellular diagnosis or for novel therapies will be detailed (including photoactivable biomolecules, NIR probes for image guided therapy, biphotonic and super resolution techniques) (Bich Thuy Doan; 6h).
(iv) **Radiation-based analysis, from spectroscopy to imaging (part II):** The course will cover a range of optical and scattering-based methods, used to characterize structures at the nanometer to micrometer length scalesThe theory of scattering (light, small angle X-ray) will be established. Models of scattering patterns will be presented to determine molecular weight, radii, shape, and impact of inter-molecular attraction/repulsion forces involved in molecular assemblies, macromolecules, colloids, up to spatial organization of biological matter. (Christophe Tribet; 6h).

Learning goals

The student should be able to:
- Identify the steps of an analytical process, know the principal processes and techniques for the sampling, sample treatment and analytical determination
- Know the more common formats and detection methods used for the environmental and biological analysis
- Understand the general principle of Magnetic Resonance methods and MR imagings.
- Understand optical methods for mesostructure characterization (microscopies, elastic static scattering, tracking)

Pre-requisites

Basics in atoms and molecules energy levels, molecules interactions, complexation, magnetic resonance and optical spectroscopy. Basics in physical and analytical chemistry, chemistry of solutions & molecular interactions. Basics in optics and interferences

C&I M1	S1	**Course Title: Theoretical Chemistry and Modelling – Advanced Modelling and simulation in chemistry** *Keywords:*
Instructor(s), Coordinator		Name(s) and e-mails: Carlo Adamo (carlo.adamo@chimieparistech.psl.eu), Frédéric Labat (frederic.labat@chimieparistech.psl.eu), Damien Laage (damien.laage@ens.psl.eu)
ECTS : 3	*Total hours : 24h*	*rating: final written exam (67%), intermediate reports (33%)*

Description

Advanced electronic structure methods enabling the treatment of electron correlation will be introduced focusing on Density Functional Theory. The coupling and extension of ab-initio approaches to describe condensed phases (solution, solids, interfaces and surfaces) will be detailed. Multi-layer methods combining Quantum and Classical approaches will be introduced for the simulation of complex environments.
Example of academic and industrial applications of these QM and mixed QM/MM methods to model i) chemical reactivity and catalysis (homogenous and heterogeneous) and ii) macroscopic properties of materials for energy production and storage and iii) biomolecules will be provided.

Based on the concepts of statistical physics and thermodynamics, molecular simulation has developed as a way to obtain information about the physical and chemical properties of a given complex system. We will introduce the students to the main classes of molecular modelling methods, molecular dynamics and Monte Carlo simulations. We will learn to study reactivity in condensed phases, both from the theoretical and computational points of view. We will contrast the approaches of quantum chemical and classical methods, and provide an introduction into mesoscale modeling methods, such as lattice-based simulations and kinetic Monte Carlo.

The course will use examples from a wide variety of fields, and demonstration applications of the methods and theories in the areas of chemistry in the liquid phase, at interfaces, for materials, and biological systems.

Learning goals

The student should be able to:

- understand the fundamentals of Density Functional Theory
- understand how one can simulate periodic systems
- understand the fundamentals of molecular simulation in chemistry, and their ties to statistical mechanics
- know differences between molecular simulation techniques
- choose an appropriate simulation technique for a given complex question
- read a computational chemistry article and understand the methodology and its limitations

Pre-requisites

BSc level in statistical physics, quantum chemistry, physical chemistry

C&I M1	S1	**Course Title: Smart Materials Chemistry – Advanced** ***Materials design and properties*** *Keywords:* Advanced functional materials. Hybrid materials. Energy storage and conversion. Batteries. Optical Materials. Metal Organic Frameworks, Stimuli-responsive materials

Instructor(s), Coordinator	A. Tissot 6h (antoine.tissot@ens.psl.eu), A. Grimaud 6h (alexis.grimaud@college-de-france.fr), B. Viana 6h (bruno.viana@chimieparistech.psl.eu), Y. Tran 6h (yvette.tran@espci.fr)

ECTS : 3	*Total hours : 24h*	*rating: final exam (written), intermediate exams, assignments, reports*

Description

This course will provide at first the necessary skills to design smart materials. The focus will be: how to start from these concepts to develop smart materials. The relevant applications of the advanced functional materials will be described as well as their fate and recycling issues.

- Description of basic concepts of coordination chemistry including geometry/reactivity/stability of coordination complexes.
- Ligand field theory, electronic properties of solids.
- Electronic transitions in rare-earths and transition metal doped materials.
- Diffusion properties in solids and quick recapitulative about electrochemistry and its application to solids and solid/liquid interfaces.
- Triggering of a stimulus such as temperature, pH, salt, light, electric and magnetic fields.
- Inducing changes of molecular conformation (surfactants, polymers) and/or changes of assembling (gels, colloids, emulsions).
- Control of macroscopic properties (rheological, mechanical, interfacial as wetting, adhesion, friction).

Toward applications

=> Synthesis, properties and applications of crystalline porous solids (Metal-Organic Frameworks).
=> New developments of batteries: which battery/chemistry for which application? Current research trends in battery performances and chemistry: tradeoff between energy/power density and scalability. Recycling issues
=> Materials for lasers, scintillation, photovoltaics and imaging
=> Materials and biotechnologies (encapsulation, microfluidics, injectable gels, photonic crystals…)

Furthermore, materials sustainability will be envisioned: can smart materials be sustainable and what are the bottlenecks to tackle?

Learning goals

At the end of this course, the student will be able to acquire the following knowledge and skills in the various fields:

- Structure and reactivity of coordination compounds
- Description of the properties of porous solids
- Photon, electron and phonon properties relationships. Radiative and non-radiative relaxations.
- Color and luminescence
- Redox properties of solids and alkali-cation diffusion properties in solids
- Charge transfer at solid/liquid interface
- Concept of stimuli-responsiveness
- To pilot molecular changes for microscopic/mesoscopic/macroscopic changes

Pre-requisites

Basics of inorganic and organic chemistry, coordination chemistry. Basics of soft matter. Thermodynamics. Basics courses of the Graduate Program.

SEMESTER 1

Innovation and soft skills

C&I M1	S1	**Course Title: Innovative Transdisciplinary Project** *Keywords: innovation, scientific project*
Instructor(s), Coordinator		Name(s) and e-mails : Fethi Bedioui (fethi.bedioui@chimieparistech psl.eu), Guillaume Lefèvre (guillaume.lefevre@chimieparistech psl.eu)

ECTS : 3	*Total hours : 54h*	*rating: final report and oral presentation*

Description

The students must design a scientific and innovative project based on research topics developed in PSL laboratories in order to gain awareness of the transformation of research results into innovative applications. Their projects will be carried out in strong interaction with these laboratories.

Learning goals

The student will become familiar with project design and planning, group work and multi-partner interaction.

Pre-requisites

none

Entrepreneurship and Soft Skills

C&I M1	S1	**Course Title: Design Thinking** *Keywords: design, innovation*
Instructor(s), Coordinator		Name(s) and e-mails: Faustine Vanhulle, Damien Ziakovic, Marc Dolger, Corinne Soulié, Hélène Montès
ECTS : 2	*Total hours : 35h*	*rating: written exam (30%), intermediate assessments (35%), oral presentation (35%)*

Description

This course aims at showing how to imagine a material / innovate for a specific object by interacting with other actors such as designer, marketing manager, etc…

In this course, the "Design Thinking" approach is presented and applied to a real innovation issue. In 2019, the theme was "personalised care" proposed by LVMH Research.

The course is articulated between courses and workshops given by innovation advisors, designers and scientific researchers. It takes place over one quarter, with a dedicated week in November and a few isolated sessions of 2 or 3 hours upstream and downstream.

The initial problem is first analysed (example of the existing situation, surveys, tests) and then repositioned in an innovative approach (responding to a real identified need). The analysis and repositioning methods are based on ideation sessions, the preparation of a trend book, tests and surveys.
Intermediary presentation sessions allow to iterate the process, to refine the positioning, to define the technical feasibility and the business model and to check the sustainability of the proposed solution.

The solutions selected for their innovative potential are developed during a dedicated week at the end of January, preceded by a presentation session at the beginning of January.

Learning goals
- identify innovation in a specific field (do not confuse innovation and invention…)
- mobilize design thinking tools to generate innovative ideas, test them, etc.
- mobilise the designer's tools to position his ideas in relation to the existing market (trend book)
- confronting one's ideas with existing or implementable technical feasibility
- take into account the development of its ideas (marketing, target audiences, sustainability by industry)

Pre-requisites
none

C&I M1	S1	**Course Title: PSL I-teams workshops** *Keywords: innovation, entrepreneurship*
Instructor(s), Coordinator		Name(s) and e-mails : Nadine-Eva Jeanne (nadine-eva.jeanne@psl.eu), Karla Balaa (karla.balaa@psl.eu)
ECTS : 1	*Total hours : 16h*	*rating: validation*

Description

This course aims at developping entrepreneurship skills and exposing to the challenges of innovation. It will provide students with hands-on introduction to the valorisation of research results and the creation of companies.

Learning goals
The student will become familiar with idea conceptualization, go-to-market strategy, market study, project developpement, management, law and financial aspect of companies.

Pre-requisites
none

C&I M1	S1	**Course Title: Language** *Keywords:*	
Instructor(s), Coordinator		Name(s) and e-mails : Daria Moreau (daria.moreau@chimieparistech.psl.eu)	
ECTS : 1	*Total hours :*		*rating: intermediate assessments*
Description Students are offered courses in various languages (French for foreigners, English,…)			
Learning goals Develop student's proficiency in foreign language			
Pre-requisites none			

SEMESTER 2

SUPER-ADVANCED CHEMISTRY COURSES

Chemical Biology

C&I M1	S2	**Course Title: Chemical Biology** *Keywords: Nucleic acids, Modified-Nucleic acids, Synthesis, Biochemistry, Chemical Biology Applications, peptide, protein, solid phase synthesis, biotechnology, fluorescence spectroscopy, fluorophores, fluorescence imaging; biomolecules*
Instructor(s), Coordinator		Name(s) and e-mails Daniela Verga (daniela.verga@curie.fr), Nicolas Delsuc (nicolas.delsuc@ens.psl.eu), Anton Granzhan (anton.granzhan@curie.fr), Blaise Dumat (blaise.dumat@ens.psl.eu)
ECTS : 3	*Total hours : 24h*	*rating: final written exam*

Description

1) Chemical Biology of modified –Nucleotides and –Nucleic Acids (6h, D. Verga)

In this section, we will focused our attention on the methods for obtaining modified and native nucleic acids and their biological applications. Several specific topics will be faced during the class:

- Chemical synthesis of modified nucleosides, nucleotides, and oligonucleotides concerning both DNA and RNA;
- Expansion of the genetic alphabet in nucleic acids by creating new synthetic nucleobases and as a consequence new base-pairs;
- The concept of chemical biology applied to DNA replication, by probing DNA polymerase selectivity mechanisms with modified nucleic-acid-template chemistry;
- The interactions of small synthetic molecules with DNA and effects produced on biological processes, and more specifically on replication and transcription;
- At last, DNA methylation as epigenetic mechanism involving the transfer of methyl groups on DNA nucleobases and effects produced on gene expression.
-

2) Peptides and Proteins synthesis, application to peptide biological activity (8h, N. Delsuc)

This section aims at giving an overview of the different approaches used to synthesize peptides and proteins. This will include chemical synthesis in solution and on solid support and chemical reactions to perform ligation enabling the synthesis of long sequences. The chemical part will include the reactions required to form efficiently amide bonds while preserving the enantio-purity of amino acids as well as protecting group management.

The course will also deal with the synthesis of proteins using new biotechnological tools involving bacteria as well as procedures to ensure an appropriate folding of the proteins. In particular, the controlled formation of disulfide bridges will be discussed. Several examples of biological active peptides and proteins already on the market will be shown to illustrate these strategies.

3) Molecular design strategies for fluorescent probes (12h, A. Granzhan, B. Dumat)

Due to its versatility, ease of implementation and high spatial and temporal resolution, fluorescence has become a ubiquitous tool in chemical biology to monitor biological processes *in vitro* or *in vivo*. Fluorescent reporters, or probes, can be used for very diverse applications, ranging from *in vitro* analytical applications to *in vivo* imaging, which call for very different requirements in terms of photophysical and biochemical properties. The goal of his course is to present the different molecular design strategies currently used to elaborate and tailor fluorescent probes for various applications. After a presentation of the underlying phenomenon of molecular fluorescence, we will cover different classes of fluorophores (from the classically used ones to the newest additions to the field), photophysical principles governing the operation of different types of fluorescent reporters, and consider various examples of the probes used for the detection, labeling and imaging of biomolecules (such as nucleic acids, proteins, enzymes…) and biologically relevant analytes (metal ions, anions, reactive species, etc.).

Learning goals

The student should be able to:

- Present the synthetic pathways employed for the preparation of both modified and native nucleic acid;
- Describe the applications of modified nucleotides and oligonucleotides
- Describe the synthesis of new synthetic nucleobases and their biological applications;
- Explain the mechanisms that allow specific DNA polymerases to incorporate modified-nucleotides and recognized modified DNA templates;
- Mention the structural characteristics allowing small molecules to interact with specific DNA structures and explain the exploitation of such interactions;
- Explain the natural DNA modifications why they occur and explain their effects in gene expressions.

- Master the different steps of the chemical synthesis of peptides and proteins and the requirements to produce enantiopure peptides and the different steps to produce recombinant proteins using bacteria
- Propose strategies to synthesize proteins
- Understand the principles of molecular fluorescence
- Know various applications of fluorescence in chemistry and biology such as structural or analyte sensing, imaging
- Know the most widely used classes of fluorophores and their characteristics, be able to identify the fluorescent scaffolds;
- Understand the photophysical and supramolecular principles governing the operation of fluorescent probes and requirements for a given application
- Tailor a fluorescent probe for a given application by combining the proper fluorescent scaffold with the adequate functional groups while taking into account the synthetic feasibility

Pre-requisites

Knowledge in organic chemistry and basic knowledge in biochemistry, organic synthesis: (orthogonal reactions, protecting groups), basics in cellular biology (protein expression), heterocyclic chemistry, physical chemistry

Advanced theoretical and computational chemistry

C&I M1	S2	Course Title: **Advanced theoretical and computational chemistry** *Keywords:*

Instructor(s), Coordinator	Name(s) and e-mails Ilaria Ciofini (ilaria.ciofini@chimieparistech.psl.eu); François-Xavier Coudert (fx.coudert@chimieparistech.spl.eu)	
ECTS : 3	*Total hours : 24h*	*rating: final written exam (67%), intermediate reports (33%)*

Description

The course will provide an advanced perspective both on theoretical models and simulation techniques treating several among the topics detailed below. Regarding numerical simulations, building o
n the introduction given in the advanced class, this course will address a range of modern techniques, including first-principle methods, extended statistical ensembles, description of nuclear quantum effects via path-integral simulations, multi-scale strategies, and the combination with machine learning approaches. Various applications of these techniques to condensed phase chemistry will be studied. This course will also present advanced theoretical models to describe chemical reactivity; starting from Transition State Theory, the course will introduce the concept of friction on barrier-crossing, its formal description via stochastic approaches and will finally address the complex case of non-adiabatic chemical reactions.
Concerning electronic structure methods, the course will explicitly address state of the art methods enabling the first-principle simulation of spectroscopic properties of molecules and extended systems. Perturbative and variational methods allowing to obtain accurate vibrational spectra will be introduced and compared to approaches based on dynamical approaches. Linear response –in the framework of the Time Dependent DFT approach- will be introduced and the simulation of the photophysical properties of molecular and extended (3D, 2D, 1D) systems will be discussed.
The accuracy and the limit of these methods (coupled with embedding techniques and/or multi-layer approaches to simulate the environment) will be illustrated through selected examples.

Learning goals

The student should be able to:

- understand the main concepts related to the modeling of spectroscopic properties of molecules and extended systems
- list the tradeoffs involved in different molecular simulation techniques
- write up a work plan for a multi-scale simulation strategy
- compare experimental data, computational results, and theoretical models of reactivity
- understand articles on machine learning techniques applied to chemistry

Pre-requisites

BSc level in statistical physics, quantum chemistry, physical chemistry

Electronic Properties of Solids

C&I M1	S2	**Course Title: Electronic Properties of Solids : from Concepts to Devices** *Keywords: band structures, optical and electrical properties, semiconductors, devices*

Instructor(s), Coordinator	Name(s) and e-mails: Laurent Binet, Pascal Loiseau, Frédéric Wiame Laurent Binet (laurent.binet@chimieparistech.psl.eu)

ECTS: 3	*Total hours : 22,5h*	*rating: final written exam*

Description

The aim 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 the course introduces the basic concepts and models (free electron gas, tight-binding) for the electronic band structures of solids and shows how these models explain the main classes 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 details the phenomena that occur in a p-n junction. The applications of such junctions are described, in particular solar cells, photodiodes and light-emitting diodes.

Learning goals

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.

Pre-requisites

quantum mechanics (Hamiltonian, operators, Dirac notation, model quantum systems), electronic structure of atoms and molecules (atomic orbitals, molecular orbitals, bonding/antibonding orbital), crystallography (crystal systems, normal lattice, reciprocal lattice), general physics (classical mechanics, electrostatics, waves), maths (integrals, partial derivatives, differential, laplacian, gradient, divergence)

Soft Matter and Developpement

C&I M1	S2	**Course SuperAdvanced : Soft matter and Development** *Keywords: soft matter, polymers, liquid crystals, colloids, formulations*
Instructor(s), Coordinator		Name(s) and e-mails: Michel Cloître (michel.cloitre@espci.fr)
ECTS : 3	*Total hours : 26h*	*rating: final written exam*

Description

The Soft Matter and Development course, designed for physicists, chemists and physico-chemists, illustrates how a good knowledge of basic concepts in Soft Matter, with an interdisciplinary approach, allows you to design and develop innovative materials and processes.

Course's content.

1- Macromolecular engineering : polymer blends, block copolymers, microphase separation of block copolymers, thermoplastic elastomers, nanostructured materials, analogy with surfactants phases

2- Molecular engineering : phases of liquid crystals (nematic, smectic, chiral), defects and textures, liquid crystal displays and other display devices

3- Colloidal engineering : hard spheres suspensions, glasses and colloidal crystals, development of photonic materials, deformable colloids (emulsions, microgels, micelles…), jamming transition

4- Formulations in solution: polymers in diluted and semi-diluted solutions, physical and chemical gels, stimuli-responsive polymers, gels and biomaterials, polyelectrolytes, associative polymers

Course support:
• Richard A.L. Jones, Soft Condensed Matter, Oxford University Press
• Masao Doi, Soft Matter Physics, Oxford University Press

Learning goals

The student must be able to:
- mobilize knowledge to solve a complex problem
- critically analyze a scientific article
- interpret experimental data and modelize them
- relate macroscopic behavior to microscopic phenomena
- draw analogies between different issues
- use English scientific and technical vocabulary

Pre-requisites

Basics of thermodynamic and statistical physics: entropy, enthalpy, phase separation, molecular forces. Basic knowledge of rheology. Basic knowledge of the structure of materials

Inorganic Materials
includes the "Inorganic Assemblies" course and the "Synthesis of Inorganic and Hybrid Materials course" (next page)

C&I M1	S2	**Course Title: Inorganic assemblies** *Keywords:*
Instructor(s), Coordinator		Name(s) and e-mails: Philippe Barboux (philippe.barboux@chimieparistech.psl.eu)
ECTS :	*Total hours : 15h*	*rating: final written exam*

Description

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 goals

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 simples 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
- He can have a view of the applications in various domains such as energy, environment, information storage, nanotechnologies.

Pre-requisites

Atomistic, Chemical bonding, electronic structure of atoms and molecules (atomic orbitals, molecular orbitals, bonding/antibonding orbital, crystal field), crystallography (crystal systems, normal lattice, reciprocal lattice), general physics.

C&I M1	S2	**Course Title: Synthesis of Inorganic and Hybrid Materials** *Keywords: Inorganic materials, porous solids, synthesis, challenges*

Instructor(s), Coordinator	Name(s) and e-mails: Sandrine Ithurria, Thomas Pons, Vanessa Pimenta, Christian Serre (sandrine.ithurria@espci.fr)	
ECTS :	*Total hours : 14h*	*rating: final written exam*

Description

The « Chemistry for Functional Materials » course is dedicated to chemists who wish to develop a broader view on the synthesis and characterization of inorganic materials and functional hybrids.
The course contains two (equal) parts: crystallized inorganic materials (7 hours) and crystallized porous materials (7 hours). For both classes of materials, the methods of synthesis and the challenges related to their characterization will be addressed, as well as their potential applications in various fields (health, energy, environment, optoelectronics). Few hours of tutorial will complement this course.

Course's content.
1. Introduction to porous crystalline solids (zeolites, clays, LDH, MOFs, hybrid cages)
2. Methods of synthesis and modulation of porosity (exfoliation, composites…)
3. The challenges of characterizing porous networks (BET, in-situ IR, solid NMR, MET, modeling)
4. Potential applications of porous solids (environment, energy, health)
5. Outlook – scaling up, shaping and industrialization (marketing, proven applications)
6. Introduction to advanced inorganic materials
7. Methods for the synthesis of inorganic materials
8. Characterization methods
9. Applications of advanced inorganic materials

To deepen your knowledge:
F. Schüth, K. S. W. Sing, J. Weitkamp, Handbook of Porous Solids, Wiley
Print ISBN:9783527302468 |Online ISBN:9783527618286
|DOI:10.1002/9783527618286

Learning goals
The student must be able to:
- identify the different classes of inorganic and hybrid crystalline materials…
- describe the different modes of synthesis of functional materials
- relate structural characteristics to material properties
- discuss the characterization methods
- consider the potential applications of crystalline functional materials
- analyze and identify important results of scientific publications
- explain concepts and ideas in a short presentation
- use English scientific and technical vocabulary

Pre-requisites
Basics of structural and solid state chemistry
Basics of coordination chemistry

Bio-analytical Chemistry

C&I M1	S2	**Course Title: Bio-analytical Chemistry** *Keywords: analytical systems, engineering, process miniaturization, innovation, engineering*
Instructor(s), Coordinator		Name(s) and e-mails : Fanny d'Orlyé (fanny.dorlye@chimieparistech.psl.eu)
ECTS : 3	*Total hours : 24h*	*rating: final written exam + intermediate rating*

Description

Developments and trends in modern analytical chemistry point in the direction of simplification, automation and miniaturization of processes while preserving the performance and reliability of the analytical results. The opportunities and challenges inherent in miniaturization at each stage of an analysis processes are very different and need to be addressed. The main objective of this course is therefore to provide a comprehensive overview of current innovations in the field of analytical systems. The final objective is the development of micro(nano)sensors and total analysis microsystems (µTAS) for the biotechnology and clinical diagnostic applications.

Learning goals

The course will focus on new analytical and bioanalytical tools for downscaling several laboratory operations (sample introduction, processing, separation, detection) in order to process extremely small volumes of fluids and also to integrate the above-mentioned processes on a device miniaturized of a few square centimetres allowing for high-speed automation and processing of analysis.

The main competences to be acquired by the students will concern:

1) new nanomaterials functionalized for diagnostics: (nanosupports, nanoparticles, nanotubes, monoliths, molecular printed materials, etc.), selective agents (antibodies/proteins, aptamers, chelating agents...) and procedures for conjugation;

2) the development of miniaturized separation methods (chromatographic or electrokinetics) mainly based on molecular recognition to purify, concentrate and isolate analytes of interest;

3) the detection in miniaturized analytical systems (optical, electrochemical, mass spectrometry);

4) The analytical processes ranging from standard bioassays to micro(nano)sensors and total analysis microsystems for biotechnology and clinical diagnostic applications.

Pre-requisites

basic notion in solutions thermodynamics, non-covalent interactions, colloïds, electrochemistry and separation methods

Physical Chemistry for Bio-systems
includes the "Bio-interfaces" course and the "Colloids and biomolecules" course
(next page)

C&I M1	S2	**Course Title: Bio-interfaces** *Keywords: surface, composition, reactions, techniques, biomolecules*
Instructor(s), Coordinator		Name(s) and e-mails : Anouk Galtayries (anouk.galtayries@chimieparistech.psl.eu)
ECTS :	*Total hours : 15h*	*rating: final written exam*

Description

This lecture aims at showing that the key role played by the surface of materials in the issues related to the interfaces between solids and biological environment (biointerfaces). These issues are mainly in the biomedical context but also, more widely, for any innovative systems implying surfaces and biomolecules (biosensors, biofilms in food industry, biocorrosion…).

This course implies the following items:

- Introduction: the surface = a complex material (structure, composition, model surfaces, real surfaces
- Biointerfaces; where all biological processes occur
- Dedicated physico-chemical characterization techniques: in situ real time ones, UHV techniques, combination of techniques morphology and composition…
- Different examples of surface reactivities from amine acid reactions to protein non specific and specific interactions

Interactivity on specific topics: understanding the quantitative approach

Learning goals

- The student will take into account the outermost layers in a material issue.
- The student will know the principles, advantages and drawbacks of some characterization techniques of solid surfaces/materials
- The students should be able to propose quantification and qualitative approaches when discussing a biointerface characterization strategy
- The students should be able to identify the properties of biomolecules adsorption, and impact on further reactions, and to model an experiment to understand surface reaction mechanisms in the frame of biomaterials.

Pre-requisites

none

C&I M1	S2	**Course Title: Colloids and Biomolecules** *Keywords:*	
Instructor(s), Coordinator		Name(s) and e-mails : Jérôme Bibette (jerome.bibette@espci.psl.eu)	
ECTS :		*Total hours : 10h*	*rating: final written exam*

Description

The key topics addressed in this course are :

• How do collids diffuse in their environement via brownian motion?

• How do colloids and biomolecules react and associate in a complex medium? How to model ligand-receptor interactions on cell membranes?

• What is the dissociation dynamics of bio-complexes and how to studt the properties of these associations?

• How to apply colloidal science to medical diagnostic?

Learning goals

The student should be able to:

- explain and predict the diffusion of colloids in a complex medium
- explain and model interactions at stake between colloids and biomolecules
- explain and predict the association/dissociation dynamics
- relate the associations and their dynamics to the properties of the macroscopic systems
- propose medical diagnostic

Pre-requisites

Organometallic Chemistry
includes the « Bio-inorganic chemistry course" and the "Heteroelements and applied catalysis" course (next page)

C&I M1	S2	**Course Title: Bioinorganic chemistry** *Keywords: bioorganometallic chemistry, enzymes, inorganic chemical biology, medicinal inorganic chemistry, metal complexes*
Instructor(s), Coordinator		Gilles Gasser gilles.gasser@chimieparistech.psl.eu
ECTS	*Total hours: 15h*	*rating: final written exam*

Description

The vast majority of drugs used today are purely "organic" compounds – they do not contain any metal atoms. However, due to their different kinetic, geometric and electronic properties, metal complexes can undergo reactions which are not possible with organic agents. With the exception of cisplatin and its derivatives, metal-containing drugs, particularly organometallics, have been, until very recently, largely neglected by both the pharmaceutical industry and academia. Over the last few years, however, things have changed, and significantly! Indeed, "inorganic drug candidates" are beginning to enter clinical trials, with more promising lead structures in the pipeline.

Learning goals

This course will cover the latest advances in the field of medicinal inorganic chemistry with an emphasis on the discovery of new inorganic compounds with proven anti-cancer activity, enzyme inhibition or anti-malarial properties. Moreover, the specific mechanism of action of the metal-based drugs will be presented in detail.

Pre-requisites

This course requires basic knowledge of inorganic chemistry and biochemistry.

Teaching language: english
Lecture notes: yes
URL:

C&I M1	S2	**Course Title: Heteroelements and Applied Catalysis** *Keywords: catalysis, transitions metals, coupling reactions, heteroelements*

Instructor(s), Coordinator	Name(s) and e-mails : Phannarath Phansavath (phannarath.phansavath@chimieparistech.psl.eu)

ECTS :	*Total hours : 12h*	*rating: final written exam*

Description

The course Heteroelement Chemistry aims at introducing the various methode for preparing phosphorus, sulfur and silicon reactants. The main transformations achieved with these compounds are given with applications in total synthesis. The goal of the course Applied Catalysis is to provide with the bases of organometallic chemistry involving transition metals (palladium, rhodium and ruthenium), as a tool for the developpement of synthetic processes. Coupling reactions and other major applications in homogeneous catalysis are introduced with a focus not only on reaction mechanisms and but also on applications, both at industriel level and for the synthesis of natural molecules or molecules of biological interest.

Learning goals

At the end of the course, the students should be able to master the methods to perform the main transformations achieved with phosphorus, sulfur or silicon derivatives and to explain the corresponding reaction mechanisms. They should be able to use the organometallic complexes suitable for the main coupling reactions and other major reactions used in homogeneous catalysis.

Pre-requisites

Good knowledge of basic reactions in organic chemistry and goog understanding of classical reaction mechanisms.

SEMESTER 2

Innovation and soft skills

Entrepreneurship and Soft Skills

C&I M1	S2	**Course Title: Design Thinking** *Keywords: design, innovation*
Instructor(s), Coordinator		Name(s) and e-mails: Faustine Vanhulle, Damien Ziakovic, Marc Dolger, Corinne Soulié, Hélène Montès
ECTS : 3	*Total hours : 35h*	*rating: written exam (30%), intermediate assessments (35%), oral presentation (35%)*

Description

This course aims at showing how to imagine a material / innovate for a specific object by interacting with other actors such as designer, marketing manager, etc…

In this course, the "Design Thinking" approach is presented and applied to a real innovation issue. In 2019, the theme was "personalised care" proposed by LVMH Research.

The course is articulated between courses and workshops given by innovation advisors, designers and scientific researchers. It takes place over one quarter, with a dedicated week in November and a few isolated sessions of 2 or 3 hours upstream and downstream.

The initial problem is first analysed (example of the existing situation, surveys, tests) and then repositioned in an innovative approach (responding to a real identified need). The analysis and repositioning methods are based on ideation sessions, the preparation of a trend book, tests and surveys.
Intermediary presentation sessions allow to iterate the process, to refine the positioning, to define the technical feasibility and the business model and to check the sustainability of the proposed solution.

The solutions selected for their innovative potential are developed during a dedicated week at the end of January, preceded by a presentation session at the beginning of January.

Learning goals

- identify innovation in a specific field (do not confuse innovation and invention…)
- mobilize design thinking tools to generate innovative ideas, test them, etc.
- mobilise the designer's tools to position his ideas in relation to the existing market (trend book)
- confronting one's ideas with existing or implementable technical feasibility
- take into account the development of its ideas (marketing, target audiences, sustainability by industry)

Pre-requisites

none

C&I M1	S2	**Course Title: PSL I-teams workshops** *Keywords: innovation, entrepreneurship*
Instructor(s), Coordinator		Name(s) and e-mails : Nadine-Eva Jeanne (nadine-eva.jeanne@psl.eu), Karla Balaa (karla.balaa@psl.eu)
ECTS : 1	*Total hours : 16h*	*rating: validation*

Description

This course aims at developping entrepreneurship skills and exposing to the challenges of innovation. It will provide students with hands-on introduction to the valorisation of research results and the creation of companies.

Learning goals

The student will become familiar with idea conceptualization, go-to-market strategy, market study, project developpement, management, law and financial aspect of companies.

Pre-requisites

none

C&I M1	S2	**Course Title: Language** *Keywords:*
Instructor(s), Coordinator		Name(s) and e-mails : Daria Moreau (daria.moreau@chimieparistech.psl.eu)
ECTS : 3	*Total hours :*	*rating: intermediate assessments*

Description

Students are offered courses in various languages (French for foreigners, English,…)

Learning goals

Develop student's proficiency in foreign language

Pre-requisites

none

SEMESTER 2

Internship and seminars

Internship

C&I M1	S2	**Course Title: Pre-internship Project and Seminars** *Keywords:*	
Instructor(s), Coordinator		Name(s) and e-mails :	
ECTS : 3		*Total hours :*	*rating: written report and oral presentation*
Description The pre-internship project consists in a bibliographic study in connection with the internship research topic. The students should become aware of the state of the art of the topic and gain a deep understanding of the principles of the techniques to be used during the laboratory work. The seminar work consists in a short written summary of selected seminars attended during the academic year.			
Learning goals The aim of this activity is to extend the scientific knowledge of the students and to make them aware of up-to-date research topics. The student should then be able to read and understand scientific academic literature to get into an unknown topic.			
Pre-requisites none			

C&I M1	S2	**Course Title: Laboratory Internship** *Keywords:*	
Instructor(s), Coordinator		Name(s) and e-mails :	
ECTS : 15		*Total hours : minimum 3 months*	*rating: written report and oral presentation*
Description The internship should take place in a research laboratory either academic or in private company.			
Learning goals The student shoulb be able to conduct a small research project, to plan and carry out experiments, to understand the theoretical bases of his/her project, to interact with other researchers and staff members, to make written and oral reports of his/her results.			
Pre-requisites none			