MSc in Engineering

ESPCI 2Ã¨me annÃ©e

Program Language: French

- Physiology
- Crystalline Materials
- Chemistry and inorganic materials
- Colloids
- Analytical Sciences
- Introduction to polymer physics
- Waves and Acoustics
- Mechanics of solids and materials II
- Professional project

PHY Physiology

Lectures: 14 h - Preceptorship: 6 h - Laboratory sessions: 30 h
ObjectivesThe main objective of the course and the associated lab sessions is to present basic notions of physiology (such as homeostasis, neuro-endocrine signaling, retroaction), building up on the molecular and cell biology covered during the first year. The temporal dimension of the organism, conferred by biological clocks that rhythm our days and nights, will be briefly described. It will be developed further in the module "Le temps" of the 2nd PSL exchange week.

SyllabusGeneral organization of the lectures:
Physiology : from molecule to organism in its environment
Introduction to intercellular signaling
An example of neuro-endocrine pathway : from the retina to the synthesis of melatonin (the "night hormone")
Introduction to the cardio-vascular system
Sleep, a physiological state in search of a function

Preceptorship Study of scientific articles on the following themes:
Study of cerebral function through the use of novel technologies (ontogenetic, voltage-sensitive dye imaging, ultrafast ultrasound imaging).
Underlying mechanisms of sleep
Neuroscience article in relationship with NMR
Laboratory sessionsStudy of the human heart through ECG. This double lab session (7.5h) involves both simulation and experimental work.
Study of the regulation of glycemia (involves both simulation and experimental work)
Study of arterial blood pressure (experimental work)
Two methods to study hearing deficiencies : acoustic oto-emissions and auditory evoked potentials (experimental work)
Neurosciences : membrane properties, channels and neuronal activation (simulation)
Brain machine interfaces (experimental work)

Teaching coordinator : AndrÃ© Klarsfeld, Sophie Pezet, Thierry Gallopin
Term : core curriculum
Number of hours : 50

ECTS Credits : 4
Last Modification : Thursday 02 March 2017

MC Crystalline Materials

Lectures: 17 h - Tutorials: 8 h - Preceptorship: 2 h - Laboratory sessions: 44 h
ObjectivesThe objective of this course is to provide students with the basic tools to describe the structure and properties of crystalline materials. The course starts by the crystallographic description of crystalline matter and the presentation of associated characterisation techniques. The second part focuses on the structure of ionic crystals and the deviations from a perfect crystal, in order to understand the relationships between crystalline solid structure and physical properties

Syllabus
Solid state crystal: periodic lattices - symmetries- point symmetry groups and space groups
X-ray crystallography: reciprocal network - structure factor - structure resolutions - diffuse diffusion - experimental methods
Crystal structures: ionic and covalent crystals
Point defects - extended defects - ionic conductivity
Disorder in crystals
Quasicrystals
Structure/property relationship: Curie principle
Piezoelectric and ferroelectric materials
Tutorials
Structure, properties and synthesis of perovskites
Local atomic structure in glass oxides
solids electrolytes
metallurgy
characterization of disordered materials by X-ray diffusion
Laboratory sessions
This course also includes a practical section on the synthesis of crystalline solid materials (ceramics for electronics, mesoporous silica by sol-gel procedure, zeolites, ferrofluid, gold plasmonic nanoparticles and quantum dots) and characterisation of the materials synthesised (X-ray diffraction on monocrystal and powder, scanning electron microscope, BET, electric, magnetic and optical techniques).

Requirements
Group theory - Fourier transform

Evaluation mechanism
written examination: multiple choice problem and general problem

Teaching coordinator : Nicolas Lequeux, Sandrine Ithurria
Term : core curriculum
Number of hours : 71
ECTS Credits : 4.5
Last Modification : Tuesday 28 March 2017

CMI Chemistry and inorganic materials

Lectures: 28 h - Tutorials: 4 h - Preceptorship: 8 h - Laboratory sessions: 42 h
ObjectivesThe basic concepts of inorganic chemistry are exposed by the study of applications that use materials with specific optic, magnetic, electronic or catalytic properties. The molecular and collective aspects are treated in parallel. The progress made in synthetic chemistry and in the understanding of properties enable the development of new materials and new applications.

Syllabus
Optical properties
Crystalline field and gems
Luminescence and lasers
Electronic properties
Charge transfer and light-emitting diode
Crystalline defects and silver halide photography
Semiconductors and p-n junctions
Magnetic properties
Molecular magnetism and Prussian blue
Lanthanides
Synthesis and reactivity
Soft chemistry and inorganic polymerization
Substitution chemistry vs electronic transfer chemistry
Isomerisms and characterisations
Organometallic chemistry and catalysis
Chemical bonding (F. Volatron)
Inorganic complexes
Symmetry and nature of ligands
Tutorials
Ligand Field Theory
Solgel Chemistry
Reactivity
Organometallic Chemistry
Preceptorship
Tanabe-Sugano Diagrams
Lanthanides and luminescence
Organometallic Chemistry and Catalysis
Identification of Inorganic Compounds
Laboratory sessions
Four subjects directly related to the course are proposed. They allow an in-depth study of the basic notions while demonstrating the usefulness of chemistry and inorganic materials in modern and sometimes daily applications.
Ligand Field Theory: Cobalt rainbow; complex alcohol tester ; mordanting
V2O5 gel: solgel chemistry; electrochromic cell; semiconducting transparent electrodes
Photography: cyanotype, Prussian blue, electrochromic window, argentic photography
Light Emitting Diode with [Ru(bpy)3]2+ and Europium phosphor

Requirements

Synthesis, cristallography, electrochemistry, spectrocopies (IV-visible, NMR, IR).

Evaluation mechanism

part A (1hr): post-lab examination, no document (8/20); part B (2 hrs): problem with document (12/20); chemical bonding (0.5 hr): problem without document (0-3 pts bonus).

Teaching coordinator : Sophie Norvez, Corinne SouliÃ©, FranÃ§ois Volatron, Renaud NicolaÃ¿
Term : core curriculum
Number of hours : 82
ECTS Credits : 5,5
Last Modification : Friday 22 February 2019

COL Colloids

Lectures: 18 h
Objectives
Colloids are objects of intermediate size (mesoscopic), between 10-8 m and 10-6 m. Colloids consist of a highly divided material state in which interfaces have a predominant role. Such systems are very common in everyday life. Examples include liquid or solid sprays (mists or vapours), foams, emulsions such as milk, mayonnaise, cosmetic creams, suspensions such as Indian ink, paints, drilling mud, catalyst or ceramic precursors. The industrial scope of these system is extremely diverse and is characterised by close coupling between product synthesis, formulation and functionalisation. As a general rule, colloidal systems are relatively unstable systems in which a precarious equilibrium between various antagonistic forces is observed. The purpose of this course is to introduce this discipline in the third-year chemistry option. The aim is to present the main categories of colloids, discuss the various interactions structuring these systems and study the main strategies for stabilising and/or destabilising these "colloidal phases". This course draws on and uses knowledge acquired from other courses in the college, giving examples of application. It makes it possible to introduce some problems encountered in the fields of materials, speciality chemistry, pharmaceuticals, cosmetics, paints and coatings, water-based binders.

Syllabus
Systems at equilibrium
General introduction to liquid condensed matter
Molecular interactions
Pure liquids and phase diagram
Solutions of amphiphilic molecules
Surface and interfacial tension of solutions
Wetting and detergency
Metastable states
Dispersions
Emulsions
Gels

Teaching coordinator : JÃ©rÃ´me Bibette
Term : core curriculum
Number of hours : 18
ECTS Credits : 2
Last Modification : Friday 10 February 2017

SAN Analytical Sciences

Lectures : 10 h - Tutorials: 6 h - Preceptorship: 6 h - Laboratory sessions: 45 h
ObjectivesThere is practically no socio-economic or scientific field that can do without the contribution of analytical chemistry (food safety, environment, fraud and counterfeit, doping, historical and archaeological heritage). The characteristics of the demand are: speed, low cost, reliability, possibility to perform tests from microsamples (drop of blood, etc.), use in the field, determination of a large number of compounds from the same sample (oil products, proteomics), test of trace and ultra-trace amounts of compounds, speciation of elements, etc. Analytical chemistry has evolved greatly in the last few years to be able to respond to these demands, partly thanks to technological advances in particular in the field of separation sciences and their coupling with mass spectrometry, but also thanks to the increasing development of bioanalytical chemistry with the use of biological tools (antibodies, receptors, enzymes, DNA strands, etc.) in various immunoassays, bioassays and biosensors. We have also seen a miniaturisation of analytical techniques, which allows faster analyses and consumes less reagents and solvents for fast diagnosis. Lab-on-chips (LOCs) are in full development and use microfluids.This course is intended to provide students with the basic knowledge required for solving an analytical problem, irrespective of the source of the request. It also aims at providing the concepts necessary for the development of new methodologies, often miniaturised, a sector which is currently undergoing large-scale expansion in the field of medical and environmental diagnosis.It starts with the study of various types of interactions and interface transport methods. Irrespective of the information sought about a chemical substance (concentration, structure, chemical state, prediction of its transport or elimination, etc.) and the nature of the milieu in which it is found (chemical, biochemical, biological), the design of an analytical strategy always requires good knowledge of the interactions that bind this substance to its own milieu and in most cases the use of a separation method. The fundamental aspects of separation methods and analytical electrochemistry are then briefly presented as they are examined more thoroughly in the tutorial sessions, while their practical aspects are approached in the laboratory course. This allows more importance to be given to the use of multi-dimensional separations for the analysis of complex mixtures and in particular for proteomic analysis, to bioanalytical chemistry (immunoassays, bioassays, biosensors) and the miniaturisation as lab-on-chips.

Syllabus
Definition of the characteristics of current analytical chemistry
Separation sciences
Introduction to chromatographic methods: fundamental magnitudes and various interactions used
Gas chromatography.
Liquid chromatography (the different modes: adsorption, partitioning, ion exchange)
Detection modes and coupling with mass spectrometry
Electrokinetic methods (free capillary, micellar phase, electro-chromatography)
Trace analysis: sample treatment
Two-dimensional coupling for the separation of complex mixtures (chromatography, electrophoresis) - applications to the analysis of oil products and proteomic analysis
Electrochemistry
Fundamental aspects
Analytical electrochemistry
Bioanalytical methods
Based on structural recognition: immunoassays
Based on the mode of action: enzyme inhibition bioassays and cellular bioassays
Miniaturisation: integrated separation microsystems and lab-on-chip for total analysis
Biosensors
Tutorials
Fundamentals and Optimization

Gaz chromatography
Miniaturization in LC, Adsorption Chromatography
Partition Chromatography
Ionic Chromatography/ Size exclusion
Capillary electrophoresis
Preceptorship
Supercritical fluid chromatography, advantages-drawnbacks/interest compared with GC and LC + an article dealing with fast separations (use and interpretation of "kinetic plots")
Simple ion exchange chromatography and interest of coupled chemical reactions for selectivity, ion pair chromatography + an article about hydrophilic interaction chromatography (HILIC)
Electrophoretic miscrosystems + a presentation of the students on a research thematic proposed by each preceptor (GCxGC, LCxLC, sample handling...)
Laboratory sessions
The four week laboratory course enables hands-on experience of the different methods such as gas and liquid chromatography, electrophoresis and electrochemistry. These methods teach the fundamental magnitudes and different techniques (separation, detection, various coupled methods) enabling their implementation. The treatment of the sample associated with liquid chromatography and gas chromatography is also used on examples such as the analysis of pesticide traces in surface water and the characterisation of volatile compounds in wine.
The students will carry out fifteen different experiments during this lab course. In general, each experiment deals with a specific case, besides the more theoretical aspect of the method, of the characterisation/analysis of compounds from varied fields such as the environment, food industry, pharmaceutical and oil industry.
It is important to note that the students use the latest generation material if possible (example of liquid chromatography and mass spectrometry coupling) so that they are subsequently quickly operational both in an industrial setting and in research.

Requirements
Basic analytical chemistry (aqueous solutions, pH, complexes, redox systems).

Evaluation mechanism
Examination on the course, report for pratical works.

Teaching coordinator : JÃ©rome Vial, JosÃ© Dugay
Term : core curriculum
Number of hours : 67
ECTS Credits : 7
Last Modification : Wednesday 31 May 2017

IPP Introduction to polymer physics

Lectures: 20 h - Preceptorship: 6 h
ObjectivesThis course deals with the statistical physics approach to the study of polymers properties with an emphasis on strengthening intuitive understanding. The aim is to offer the students a good intuition for the system, the length scales, and the time scales.

Syllabus
We focus on the ideas, mechanisms, driving forces, understanding of competing interactions. Then, we

develop simple calculations which are almost always compared to experiments for verification.
Entropy of polymer chains (in relation with the Statistical mechanics module)
Intrinsic dimensions of a polymer chain (ideal/real, stretched/confined, measurement of size by scattering
Polymer blend and polymer solution (free energy of a binary mixture: entropy vs enthalpy, exclude volume concept for polymer solutions: chain size and correlation length in good solvent)
Rubber elasticity (affine network model and its limits, swelling properties of a polymer
Dynamics of conformational changes
Thermal energy /energy of weak interactions (van der Waals, H bonds...)
Time of measurement/ time of conformational changes
Different length scales: i) chain diffusion : motions of an entangled chain (example of the reptation) ; ii) glass transition: motions at length scales from the KÃ¼hn segment to the entanglement distance ; iii) characteristic times of chain rearrangement & mechanical perturbation: temperature and time dependence of the modulus E*(T, w) , viscoelasticity and time temperature equivalence, WLF law.
Preceptorship
Dimensions of a chain: conformations and properties in solution
Vitreous transition
Rubber elasticity
Links to other course modules
The concepts are presented in relation to other courses: Statistical mechanics, Optics, Mechanics of solids and materials II and Crystalline materials.

Requirements

Stress-strain response of visco-elastic solids ; thermodynamics : entropy, internal enregy, statistic of a random walk ; short range interactions : Van der Waals, H bond, etc. ; thermodynamics of binary mixtures ; conformations and configurations of a polymer chain.

Evaluation mechanism

Exam written in English in 2 parts (answers in English or French allowed): part I, 10 concept questions; part II, 5 short problems.

Teaching coordinator : HÃ©lÃ¨ne Montes
Term : core curriculum
Number of hours : 26
ECTS Credits : 2,5
Last Modification : Thursday 07 September 2017

OA Waves and Acoustics

Lectures: 19 h - Tutorials: 6 h - Preceptorship: 4 h - Laboratory sessions: 45 h
Objectives
This course aims to give a thorough grounding in the tools necessary for describing wave propagation. We propose a unified framework based on the idea that in spite of their diversity all waves obey a differential equation with the same symmetry properties: invariance under time-translation, spatial reciprocity, time-reversal invariance.

A special focus is made in acoustic waves propagating in various kinds of fluids (homogeneous, heterogeneous, bounded). Laboratory sessions, tutorials and preceptorships give the opportunity to address important issues for industry (medical imaging, non destructive testing, sonar,...) as well as more academic ones (e.g., sonoluminescence).

Syllabus
Introduction
How to build a wave ?
Wave equation and diffusion equation
Acoustic waves in fluids
Generation of acoustic waves in a fluid
Conservation laws and the equation of state
Linear acoustics
Nonlinear acoustics
Diffraction theory
Unicity theorem
The spatio-temporal Green's function
The monochromatic Green's function
Reciprocity theorem
The Helmholtz Kirchhoff integral theorem for monochromatic waves
The Helmholtz Kirchhoff integral theorem in the time domain
Wave propagation and signal theory
Diffraction as a spatial filter
Fresnel transforms and Fourier transforms
A lens as a spatial matched filter
Radar and sonar pulse compression
Tutorials
Acoustic waveguide
Diffraction impulse response of a circular transducer
Passive imaging based on noise correlation
Preceptorship
The concept of coherence in wave physics
Time Reversal of ultrasound in disordered media and wireless communications
Laboratory sessions
Ultrasound imaging
Wave propagation in complex media
Sonoluminescence
Links with other courses
Electromagnetic waves (1st year)
Mathematical methods II (2nd year)
Optics (2nd year)
Waves in Complex Media (3rd year)

Requirements

Fourier Transform

Operators : gradient, divergence, curl, Laplacian.

Evaluation mechanism

Written exam (2h30). Laboratory notebook.

Teaching coordinator : Arnaud Tourin, Fabrice Lemoult
Term : core curriculum

Number of hours : 74
ECTS Credits : 6
Last Modification : Tuesday 28 February 2017

MSM2 Mechanics of solids and materials II

Lectures: 18 h - Tutorials: 6 h - Preceptorship: 4 h
ObjectivesThis course in the Mechanics of Solids is oriented towards the mechanical properties of materials. After some revision of the fundamental concepts of stress, deformation and elastic energy (treated in the 1st year classes), we will develop the principal types of behavior showing their physical origins. Viscoelastic and plastic characteristics, and fracture of large classes of materials are considered in parallel with a study of the corresponding constitutive equations which govern their behavior. A study of simple solicitations will lead to ideas guiding the choice of a particular material depending on the application envisaged (e.g. structure and loading). A methodology with reduced formalism will be employed to address the physical modeling of more complex situations encountered in everyday life or in modern applications.

Syllabus
General notions on material strength and continuum mechanics
Classes of materials and constitutive behaviors
Solution of 3D elastic problems (stress and energy approaches, scaling laws)
Elastodynamics: waves, vibrations, shocks
Viscoelastic behavior: rheological models, time and frequency representations, polymers
Plastic behavior: 1D models, strain hardening functions
3D yield criteria and flow rule
Linear elastic fracture mechanics (stress and energy approaches)
Brittle and ductile fracture : mechanisms of energy dissipation
Contact, adhesion and friction
Instabilities and morphogenesis
TutorialsExercises from previous years exams will be addressed to get a proper training to the final exam.
PreceptorshipNovel topics are developed every year to get acquainted with scaling methods and to treat advanced topics going beyond the main core of the course.
Links to other course modulesIn the frame of the laboratory sessions of the Fluids mechanics course, 4 experiments are dedicated to solids:
measuring the stress field around a crack tip
beam vibrations
delamination of thin films
elastoplastic behavior of glassy polymers

Requirements
Fundamentals of continuum mechanics and linear elasticity (Mechanics of solids and materials I course).

Evaluation mechanism
Written examination (part A: MCQ, part B: exercices based on scaling methods).

Teaching coordinator : Matteo Ciccotti, JosÃ© Bico, Pascal Kurowski
Term : core curriculum
Number of hours : 28
ECTS Credits : 4,5

Last Modification : Thursday 01 June 2017

CRS2 Professional project

Workshops: 12 h
ObjectivesThe main objectives of this second module are:
Know how to assert your career plan while mastering recruitment techniques/processes
Get a better understanding of individual motivations within a team of co-workers in an organisation
Understand certain mechanisms of cooperation within a team towards a common goal
Learn to work with people with different personalities and cultures
Learn to step back and reflect on your own integration in a team

SyllabusRecruitment process: how to find an internship, how to write a covering letter and a resume, on-line application process, etc.
Personal skill assessment, work on the professional project and the skills necessary for the chosen orientation
The sessions include case studies, simulations and active student participation.

Teaching coordinator : Brigitte Beaussart
Term : core curriculum
Number of hours : 12
ECTS Credits : 1
Last Modification : Saturday 25 February 2017