WHITE PAPER of the CHEMISTRY RESEARCH DEPARTMENT

UNIVERSITY OF MONTPELLIER

CHEMISTRY
RESEARCH DEPARTMENT
UNIVERSITÉ DE MONTPELLIER

White Paper of the Chemistry Research Department

University of Montpellier
Chemistry for health, energy and environment

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Finally, to Chantal Salson, for the great bibliometric study and support performed during the PRIME@MUSE project.

All roles mentioned in this document are understood to be both feminine and masculine.

Contents

Introduction

The governmental initiatives I-SITE (Initiative Science Innovation Territories Economy) aimed to develop in France, thematic research-universities based on their international and scientific recognition in research, training and innovation.

The University of Montpellier was part of this I-SITE's initiative under the name: Montpellier University of excellence, MUSE, launched in 2017 with 19 institutions. This project was successfully and definitely labelled in march 2022 as a «Programme d'Excellence I-SITE (PEI)» around 16 institutions, which have together shown their capacity to build a leading university in France and Europe.

To celebrate those 5 years of efforts undertook by the entire chemistry community to the I-SITE's project, this document presents the white paper of the Chemistry Research Department part of the University of Montpellier. Indeed, a white paper is a great opportunity to review and to reflect on the development of the research in Montpellier and its future.

Thus, this booklet introduces the chemistry ecosystem of the University of Montpellier and its partners in its entirety in order to provide a better understanding of its activities and infrastructures for the scientific community, political decision-makers and industry.

Students, research support staff, researchers, teacher-researchers and management committees were all committed to construct this white paper in a collaborative approach.

It is a testimony to the determination of the Chemistry Department's community to support the positioning of the University of Montpellier among the best French universities.

This document also aims to present the ambitions, ideas and resources required by our department to build the University of tomorrow in order to better respond to the major scientific, technological, economic, environmental and societal challenges of the coming decades.

First, we invite the reader to discover the great names of local chemistry and to trace the main lines of our historical heritage as well as the advances and expertise acquired since the 17th century that have shaped the Chemistry Research Department that we know today **(part 1)**.

The Chemistry Research Department is structured around four research institutes, a laboratory of Excellence, a Carnot institute for the industrial development, three technical platforms and three training institutions: the University of Montpellier, the National Graduate School of Chemistry of Montpellier (ENSCM) and the Doctoral School Balard Chemical Sciences. The general presentation and complete overview of these researches, training and development infrastructures are presented in **parts 2 to 4**.

In a world where research is rapidly evolving, the research projects developed in the Department are focused towards societal impact, the global circular economy and taking into account the UN's Sustainable Development Goals. The **part 5** provides an illustration of the efforts, contributions and local to international partnerships of the Chemistry Research Department's teams.

The socio-economic anchoring of chemistry in Occitania and beyond is addressed in **part 6** through examples of company creation, industrial partnerships and key events.

The last part of this white paper - **part 7** - presents the reflections of our community in order to build the University of tomorrow, whilst facing the challenges of the 21st century.

1 A LEGACY, A HISTORY

History & evolution of structuring to the present day

Great personalities with a broad and industrial vision will enable Montpellier chemistry to play an academic and socio-economic role, particularly in the fields of oenology, viticulture, pharmaceuticals, industrial processes, salt marshes, textile dyes and the manufacture of raw materials.

Chemistry was first taught in Montpellier in 1676 as an integral part of the training programme for students at the Royal College of Medicine.

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Numerous doctors with a passion for chemistry contributed greatly to its positioning, not hesitating to display clear-cut and pioneering positions for the time, in favour of so-called «chemical» prescriptions, contrary to the Parisian approach.

This ideological battle over antimony lasted a century and ended with the cure of a chemical prescription of antimonial wine to a young Louis XIV in 1658. He then supported the creation in 1676 of the first chair of chemistry in Montpellier within the Royal College of Medicine, with its first laboratory welcoming 40 students. The second chair was established in 1782 in the Royal Society of Sciences under the direction of Jean-Antoine **Chaptal** (1756-1832) a physician, industrialist and chemist. A chair bearing his name was created in 1881.

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In 1808, The French revolution disrupted the scientific ecosystem and resulted in the creation of the Montpellier Faculty of Sciences with 175 students, 8 professors and a chair of chemistry. The latter was directed in 1887 by Robert **De Forcrand**, a renowned thermo-chemist. His vision of the industrial potential of chemistry led him to found the «chemical engineer» degree.

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The defeat at the hands of the Germans in 1870, which was partly due to a lack of science and technology, as well as the reforms of higher education to boost research introduced during the Third Republic, led to the emergence of different scientific centres. In 1889, the first research centre in chemical sciences in Montpellier was created under the name of the Institute of Chemistry.

The institute's research was to be recognised in the field of energy and transport by the decision of the director of the chair and of the chemistry institute, Marcel **Godechot**, a chemical engineer, in 1922 to focus on hydrocarbons as substitutes for petroleum in the internal combustion engine developed in particular by Benz in 1880.

The Institute of Chemistry became the School of Chemistry and moved into one of the most modern research structures in France, inaugurated in 1935 under the governance of Dean M. Godechot (former building of the Ecole Nationale Supérieure de Chimie de Montpellier, Boutonnet tram stop).

After the death of M. Godechot in 1939, his doctoral student Max **Mousseron** (1902-1988), a chemist and pharmacist, succeeded him in 1941 and continued his research activities in organic chemistry despite the Second World War. He contributed to its expansion and left his mark on 20th century chemistry.

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The current scientific focus is partly derived from his work in the field of biomolecular and organic synthesis. He organised the first stereochemistry congress in France and discovered the antiseptic activity of quaternary ammoniums, still used today in the formulation of biocidan® and cetavlon®.

Committed to education, in 1957 he created what is now the Ecole Nationale Supérieure de Chimie de Montpellier, ENSCM, and became the first French teacher to introduce the concept of arrows to his students to explain the electronic displacements of chemical reactions, an educational innovation.

After the war, chemistry specialised and diversified. The University of Montpellier then created various chairs in organic chemistry, mineral chemistry, biological chemistry and materials science. Germaine **Cauquil** (1897-1983) became the first woman to hold a chair in organic chemistry at the University of Montpellier in 1948.

The research areas and their chairs are still relevant today and have led to the emergence of the four institutes of the current Chemistry Research Department.

The Max Mousseron Institute of Biomolecules, which focuses on organic synthesis and in particular the development of biomolecules.

The Charles Gerhardt Institute specialised in materials science and their applications in the field of energy, environment and health.

The 4 research institutes of the Chemistry Research Department

The Marcoule Institute for Separation Chemistry, which focuses on molecular systems and materials applied to the nuclear fuel cycle and metal recycling from industrial wastes.

The European Membrane Institute specialised in membrane materials and processes and associated physico-chemical phenomena, with applications in the fields of energy, environment and health.

The beginning of the 21st century marks the scientific and geographical regrouping of all chemical disciplines. The «Pôle Chimie Balard» campus was born out of the common desire of all those involved in this project - all the staff, the supervisory bodies, the region and its former president Georges Frêche (1938-2010) - to build a centre for chemical sciences of international stature, and it will soon become France's largest site for research and training in chemistry. This historic rapprochement, initiated under the Third Republic, took shape with the opening of these new research buildings in 2022.

2000
Launch of the work on the 1st research building hosting the research institute IEM.

2007
Signature of the agreement for the creation of the "Pôle Chimie Balard".

Selection of the chemisty research development project by the State-Region CPER 2007-2013

2008
Studies for the construction of the Balard campus, including research buildings for the two research institutes ICGM and IBMM, an Analysis and Characterisation Platform (PAC), the ENSCM training premises, an Innovation and Transfer Centre and a Business Centre.

2010
Launch of the work on the IEM extension building.

2011
Creation of the Balard University Foundation.

2017
Opening of the training buildings.
Launch of work on the Balard Campus research building.

2018
Laying of the foundation for the Research building.
Launch of the I-SITE MUSE and dissolution of the Balard Foundation.

2019
Creation of the Chemistry Research Department within the I-SITE MUSE.

2021
Start of the relocation of the research teams of the IBMM and ICGM institutes and the PAC and Synbio3 technology platforms.

2022
Launch of the Chemistry Research Department within the University of Montpellier

Key stages in the birth of the «Pôle Chimie Balard» campus

Historical figures

Some historical figures have shaped the research developed today at the University's Chemistry Research Department.

1756 - 1832

Jean-Antoine Chaptal

Physician, industrial chemist trained by Lavoisier and Guton de Morveau and Laplace. He developed new industrial processes. With Etienne Bérard, they founded the company «la Paille» in Montpellier, becoming the European leader in the synthesis of sulphuric, nitric and hydrochloric acid, the synthesis of textile dyes and wine distillation processes until 1863. He invented the process that was named after him, chaptalization: it consists of adding sugar to the must to increase the alcohol content after alcoholic fermentation.

1801 - 1876

Antoine-Jérôme Balard

Discovered bromine in 1826 and participated in the industrial boom. With Henry Merle he created the Compagnie des Produits Chimiques d'Alais et de la Camargue, which was to become the multinational Pechiney in Salindres (Gard). He modernised the Hérault salt marshes by developing the crystallizers still used in Villeneuve-lès-Maguelone.

1819 - 1894

Louis Figuier

Chemist, pharmacist and doctor, was passionate about popularising science. He had great success with his scientific works, which captivated the public and made chemistry trendy.

1757 - 1837

Sébastien Lenormand

Physicist, chemist and science populariser, he invented the parachute and its name, which he later published in the annals of chemistry. He demonstrated it in 1783 at the Babote tower in Montpellier in front of Joseph Montgolfier, brother of the inventor of the hot-air balloon.

1816 - 1856

Charles Gerhardt

Became a professor of chemistry in Montpellier in 1841 at the age of 25. He developed the foundations of modern organic chemistry with over 200 papers on his theoretical and experimental work. He isolated 126 organic compounds and discovered quinoline in 1842 and acid anhydrides in 1852, which revolutionised the chemical concepts of the time and synthesised acetylsalicylic acid for the first time, creating aspirin. At a time when there was confusion between atoms and molecules, his work led to a major breakthrough in the world of atomic theories and the classification of organic compounds (alkanes and chemical functions).

1902 - 1988

Max Mousseron

Chemist and pharmacist, he is a symbolic figure of 20th century organic chemistry. He was as much involved in the development of research and training as in industrial development. He transformed the Montpellier engineering school and expanded the research facilities in 1965. This building and a research institute pay tribute to him today by bearing his name. From 1962 until his retirement, he directed the pharmaceutical research laboratory for the company CLIN-BILA, which became Sanofi-Recherche in 1981, Sanofi-Synthélabo in 1999 and finally Sanofi-Aventis in 2004.

2 GENERAL OVERVIEW

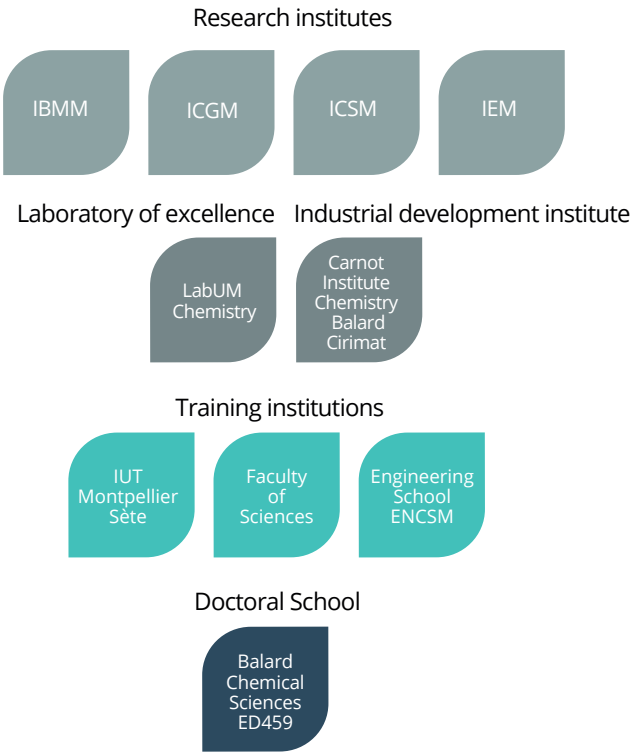
The development of Chemistry Research Department across multidisciplinary interfaces is one of the complex issues of contemporary science and one of the major challenges of the 21st century.

The ambition of the Research Department to develop and group together, in ex-Languedoc-Roussillon region, high-level fundamental and applied research in the field of chemical sciences, within the same campus «Pôle Chimie Balard» is clearly in line with this approach and that of the territorial policy, which is concerned with mankind and its environment and, moreover, creates jobs.

Although this multidisciplinarity and expertise are already recognised, this campus structure aims to amplify the development of interdisciplinary research between the various research institutes of the University of Montpellier and the region, involving interfaces with biology, health, physics, geosciences, ecology and agronomy. The Chemistry Research Department is therefore perfectly in line with the scientific policy of the I-SITE programmes of excellence in order to provide answers to the major economic and societal challenges of «Care, Feed, Protect».

This grouping also enables the Chemistry Research Department to position itself as a visible and attractive centre of excellence for research and training, federating European and international partnerships around the major issues of today's world.

Overview of the research, training and industrial institutions devoted to chemistry.



Supported and financed with €150 million by the State, the Occitanie-Pyrénées-Méditerranée Region and its founding members, the Chemistry Research Department is being developed around two sites.

The Montpellier site (Hérault)

Consisting of an ambitious and structuring building complex, it brings together on a single site, at the end of 2021, all the research, training and development skills currently found throughout Montpellier: IBMM and ICGM near the IEM, the Doctoral School Balard Chemical Sciences, technical and service Platforms, the ENSCM engineering course and the Master's technology hall.

The CEA center site (Gard)

Located in Marcoule area, it was set up a training centre to support sustainable nuclear actions. It is home to the Institut National des Sciences et Techniques Nucléaires (INSTN of Marcoule) via the global research-training project in Marcoule, as well as a research building bringing together the ICSM laboratories.

This wealth of skills brought together in academic laboratories located on the same site is exceptional. It offers a complete range of different phases of research applied to contemporary problems, both in the field of training and with industry and civil society. It is the Chemistry Research Department's major asset, with its research units serving the entire scientific community of the University of Montpellier.

The Chemistry Research Department in a few figures

WORKFORCE

4
Research institutes

35
Teams

510
Permanent

400
Temporary

1
Doctoral School

1
LabEx/LaBUM chemistry

1
Carnot Institute*

3
Technical Platforms*

**ISO 9001:2015*

BUDGET

22 M€
Consolidated/year

13 M€
Own resources/year

A DEDICATED CAMPUS

29,000 m²
surface area

INNOVATION

24
Start-ups since 2009

22
active licences

>200
Patents filed since 2014

>280
Contracts with private partners since 2014

2
Marketed drugs (Macrilen™, Sebivo)

4
Joint ANR laboratories

RESEARCH

>800
Scientific articles/year

>5.1
Average impact factor

>140
National public contracts since 2014

4
ERC (European Research Council)

8
IUF (Institut Universitaire de France)

65
CIFRE agreements

**2014-2019 period*

3 RESEARCH AREAS & THEIR APPLICATIONS

Chemistry, the science of creating molecules and materials that shape our world, is now responding to the challenge of building a sustainable society by offering innovative solutions to the various members of society in response to new contemporary requirements.

With a wide range of skills, tools and methods for characterisation and modelling, the Chemistry Research Department also works to understand, develop and optimise molecules and materials to meet their constant evolution, new functionalities and environmental requirements.

The research concerns all the major families of therapeutic molecules (organic, biomolecules, biopolymers) and materials (ceramics, composites, polymers, organic, inorganic and hybrid porous materials, biomaterials...) and applies to the following fields.

Major areas addressed by our research institutes

- Health
- Environment & circular economy
- Energy & ressource managment

Health

Human health

The chemistry teams, aware of the new paradigm that is taking place in the medical field - i.e. its shift towards preventive, predictive, regenerative, substitution, e-medicine and personalised medicine and of digital advances, are proposing innovative solutions for medical players and patients, particularly in the fields of chronic and metabolic diseases, infectious diseases and cancer.

The skills of our researchers enable the following:

• Vectorisation and targeting of biomolecules for greater efficiency, selectivity and lower toxicity.

• The development of new controlled drug delivery systems.

• The development of new therapies involved in infectious diseases due to emerging viruses (Ebola, SARS-CoV 2 and 1, MERS coronavirus, Dengue Virus and Zika), chemo-resistant bacteria, parasites (malaria), cancers, neurodegenerative diseases (Alzheimer's, Rett's syndrome...).

• The creation of bioartificial, biomimetic and bioactive organs and prostheses.

• Patient support through the development of medical devices.

• Wellness through the development of new cosmetic solutions.

• Regenerative medicine with skin carcinogenesis induced by UV radiation exposure (for example) for a better understanding of the molecular mechanisms involved from attack to protection and repair processes.

• The search for new strategies to understand the mechanisms of oxidative stress in mammals and also of toxins in insects (especially bees).

• The development of biosensors, nano-bio platforms and diagnostic methods.

• The understanding of adaptive systems to extreme conditions such as in tardigrades (extremophile animals).

Plant health

The 21st century is witnessing a profound agricultural transformation in terms of food safety, plant protection and plant health.

Phytopharmacy is gradually being replaced by new substances and new biomimetic concepts not only for the plant but also for the consumer. So, by protecting the crops, we improve their health in their environment and vice versa.

The Chemistry Research Department uses its skills to support and to accompany these developments by designing and developing, among other things:

• Methods of analysis and detection of pollutants,

• Bio-fertilizers,

• Bio-pesticides,

• Methods for studying ecosystems (disappearance of bee colonies),

• Natural defence stimulants,

• Methods for understanding plant mechanisms.

Environment & circular economy

The consideration of environmental, economic and geopolitical parameters, as well as the depletion of raw materials, are prompting the political, industrial and scientific worlds to develop channels for the recovery of secondary raw materials.

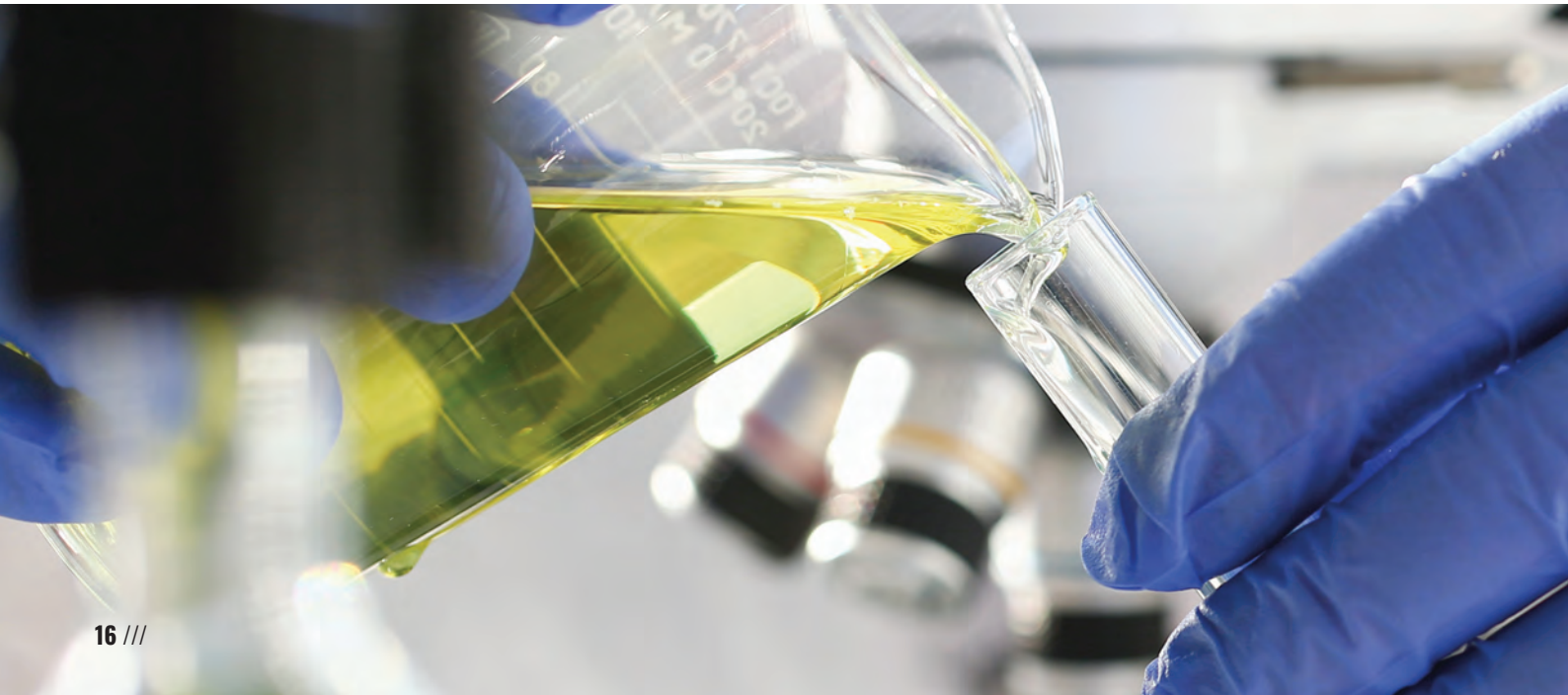
Recycling appears to be an essential way of recovering material flows from manufacturing scraps, waste or the processing of more complex objects at the end of their life.

With the acceleration of the ecological transition, the academic and industrial sectors are adapting and evolving towards new chemical practices and processes that integrate an environmental protection approach.

In this context, all the Chemistry Research teams are also involved in the development of new green chemistry processes (solvent-free chemistry or chemistry with solvents that are less toxic for humans and the environment) for the synthesis of molecules, biomolecules and materials, in the application of processes for their transfer to an industrial scale (production, treatment, decontamination, recycling) and in the use of bio-sourced, bio-inspired or recycled components in order to minimise the environmental impact.

The Department's institutes provide expertise and knowledge in the following areas:

- Extraction from ores.
- Reduction of pollution and energy costs in the hydrometallurgical sector.
- Recycling of spent nuclear fuel (dissolution, separation, containment).
- Life cycle of materials (synthesis and usage properties).
- Management of material end-of-life using short and/or green processes by selective extraction and recycling from urban mine and industrial waste, soil decontamination.
- Water treatment, industrial effluent treatment and seawater desalination.
- Reuse of wastewater and recovery of secondary raw materials (nutrients, biogas, irrigation...).
- Detection and treatment of oily effluents or micro-pollutants in water (drugs, endocrine disruptors, pesticides, organochlorines...).
- Design of eco-materials and recovery of organic matter (cereal, oyster...).
- Air quality improvement and control (gas separation, capture and detection of contaminants, separation and retention of radioactive noble gases released during severe accident).
- Reduction of the carbon footprint: from the capture of CO_2 to its use and conversion by catalytic processes.



Energy & ressource managment

In a world of finite natural resources, the production of energy from either fossil fuel, nuclear or renewable sources poses many climate and environmental problems.

The new requirements in terms of safety and waste management, but also the need for recycling, which until now has been considered exceptional, and which must become the universal and economically acceptable rule, are confronting scientists with major questions in order to provide solutions and technologies that favour decarbonised energy.

The Department's teams are involved in both fundamental and applied research in the following energy-related areas:

- Fuel cells and flow batteries.
- Photo-electro-catalytic reactors.
- Synthesis of photosensitive materials for solar energy storage.
- Materials for electrochemical storage and energy conversion (batteries, electrode materials, electrolytes, supercapacitors...).
- Nanomaterials for energy storage (thermoelectricity, piezoelectricity, mechanical).
- Materials as fuel for sustainable nuclear energy, use of biomass as an energy resource.
- Development of biofuels and synthetic fuels.
- Hydrogen vector: production, detection, purification, storage.
- Electronic components for decarbonised energy.

Summary

4 OVERVIEW OF INFRASTRUCTURES

Research, training, development and technical platforms

Placed under the auspices of multidisciplinarity, the Chemistry Research Department gathers 4 research institutes, 3 technical and service platforms, a laboratory of excellence, an institute of industrial development labelled Carnot and training establishments whose specialities offer a wide range of essential disciplinary skills to meet the challenges of the 21st century. The themes covered by the institutes integrate research at the intersection of chemistry, biology, medicine, physics and ecology, ranging from fundamental and applied research to technology development and proof of concept.

All these key players are strongly involved in the development policy thanks to the Carnot Institute, which plays a major role in technology transfer, industrial partnership and the competitiveness clusters within which they contribute to regional economic development. In ex-Languedoc-Roussillon, 145 companies are in the «chemical» sector, mainly SMEs and the pharmaceutical industry (Sanofi-Aventis, Bausch and Lomb...). The Chemistry Department is aware that the development of greater links with local private sector is important for the creation of wealth within our region.

IBMM
Institut des
Biomolécules
Max Mousseron

Keywords
Research, innovation in the synthesis, chemical reactivity, study of the physico-chemical, biological, pharmacological and toxicological properties of biomolecules.

The Max Mousseron Institute of Biomolecules

From molecule to drug - At the interface between chemistry, sustainable processes & biology

Date and context of creation: IBMM was created in 2007 under the leadership of Professor Jean Martinez in order to bring together six research units recognised for their work in the different classes of essential biomolecules.

Director: Pr. Pascal Dumy since 2015
Number of employees: 300 people (180 permanent and 130 temporary)
Label : UMR 5247
Tutelles: CNRS/UM/ENSCM

6 research departments - 13 teams
1220 publications - 53 patents including 14 licences over 6 years
60 contracts with private companies - 13 CIFRE supports in 6 years

IBMM is nationally and internationally recognised for its work in the different classes of essential biomolecules: lipids, sugars, nucleosides and oligonucleotides, peptides and proteins, prebiotic molecules and biopolymers.

The grouping of research themes around major classes of biomolecules within the same Institute is unique in France, and even in Europe.

IBMM displays its skills for integrated research, with the aim of understanding the mechanisms of life by designing molecules and systems useful for biology, medicine, and agriculture while developing green chemistry processes.

MAIN RESEARCH AREAS

1

Organic synthesis
Development of new reactions and processes, «economical» and environmentally friendly reactions, innovative technologies allowing access to biomolecules and biomaterials useful for health, the well-being of humans and their environment.

2

Biomolecules
Analysis and characterisation of biomolecules and biomaterials, as well as the study of their mechanisms of action and their involvement in physiopathological processes.

3

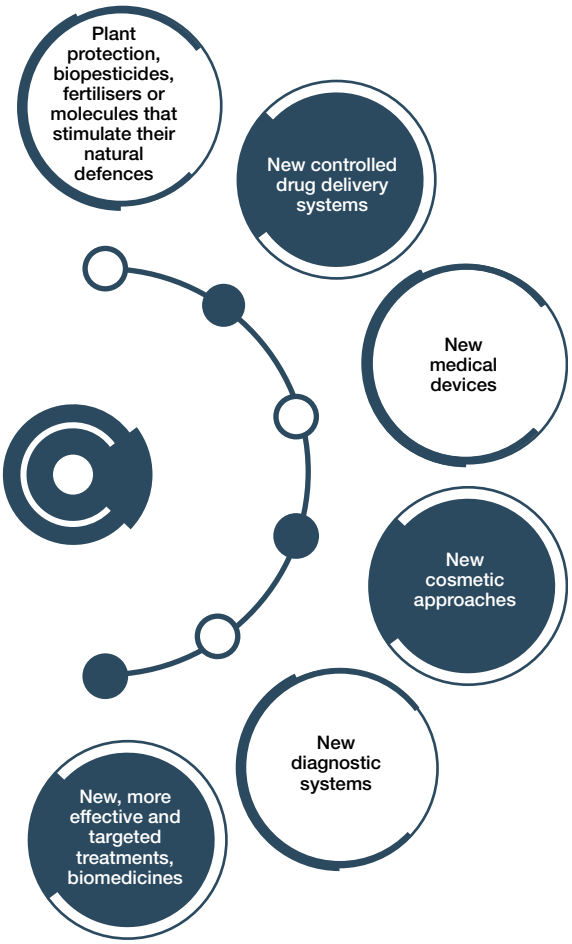
Methodologies
in cellular and molecular pharmacology, toxicology, associated with molecular modelling and bioinformatics for the discovery and selection of new molecules and biomaterials for therapeutic purposes.

4

Search for new potential therapeutic targets involved in different diseases.

AREAS OF USE

The applications of biomolecules cover a wide range of fields such as human and animal medicine, cosmetology, agri-food, veterinary industry and agrochemistry within a sustainable development framework.



AREAS OF RESEARCH AND EXPERTISE

• The search for new therapeutic targets involved in infectious diseases due to emerging viruses (Ebolavirus, SARS-CoV 2 and 1, MERS coronavirus, Dengue Virus, Zika), chemo-resistant bacteria, parasites (malaria), cancers, cardiovascular diseases and neurodegenerative diseases.

• The synthesis of more efficient and environmentally friendly biomolecules and derivatives.

• The design by molecular modelling and bioinformatics.

• The development of analytical methods for the characterisation of biomolecules and their analysis in biological media for the study of physiopathological processes.

• Pharmacological, toxicological and in vitro biological studies of these biomolecules to validate their properties and select the most promising ones for development into new therapeutic and diagnostic systems and devices.

• The study of molecular interactions, recognition phenomena to address the treatment of pathologies or the study of the mechanisms of action of ligands interacting with G-protein-coupled membrane receptors (GPCRs).

• The development of fundamental research, which has led to the marketing of two drugs (Macrilen, Sebivo) and the creation of 15 companies.

RESEARCH TEAMS

Department of Amino acids, Peptides and Proteins
- Team Amino acids, heterocycles, peptides and proteins
- Team Analytical sciences of biomolecules
- Team Cellular pharmacology
- Team Green chemistry and innovative technologies
- Team Glyco and nanovectors for therapeutic targeting
- Team Oncopharmacochemistry and cutaneous pharmacotoxicology
- Team Pharmacology of synaptic transmission and neuroprotection
- Team Photobiology, oncopharmacology
- Team Stereoselective synthesis and modified amino acids

Department of Analogues and Constituents of Nucleic Acid
- Team Chemical biology and nucleic acids chemistry
- Team Nucleotides and phosphorylated effectors

Department of Bioactive Lipid Synthesis

Department of Biomolecular Organisation
- Team Dynamics of complex biomolecular systems
- Team Supramolecular machines and architectures

Department of Glycochemistry and Molecular Recognition

Department of Polymers for Health and Materials

The Charles Gerhardt Institute Montpellier

From molecules to materials - At the chemistry & physics' interface

Date and context of creation: ICGM was founded in 2007 at the request of the Scientific Directorate (DS4) of the Ministry of Research and the Chemistry Department of the CNRS. The creation of the ICGM, together with the creation of the IBMM and the ICSM, was one of the stages in the process of structuring the Chemistry field in ex-Languedoc-Roussillon.

Director: Dr. Eric Clot, since 2021

Number of employees: ~450 people (200 permanent and 250 temporary)

Label : UMR 5253

Tutelles: CNRS/UM/ENSCM

5 scientific departments
1855 publications - 94 patents of which 7 licensed in 5 years
161 contracts with private companies - 36 CIFRE supports in 5 years

Keywords
Development, characterisation, modelling, implementation of new materials, Nanomaterials, materials for energy, optics, information storage, catalysis.

The ICGM contributes to the development of research at the highest level with the aim of elaborating and characterising complex materials with functionalities of high societal impact, particularly in the fields of health, environment and energy.

The mastery of the entire chain of skills in the development of complex materials positions the ICGM's research activities favourably in the Montpellier landscape. The project, supported by the entire UMR, «Material chemistry at the service of human beings and society» is based on five major complementary themes:

1. Molecular materials
2. Macromolecular materials
3. Porous and hybrid materials
4. Materials for energy
5. Theoretical physical chemistry

These five themes, which interact strongly with each other, enable research to be organised around the different time and space scales that need to be mastered in order to design innovative complex functional materials for applications in the fields of health, the environment and energy. One of the cornerstones of all this research is the desire to understand and use the different types of intermolecular interactions to propose synthesis strategies that highlight cooperative processes and synergies between different functional units.

MAIN RESEARCH AREAS

1

From molecule to material and its shaping to device: molecular, macromolecular and supramolecular chemistry, self-organisation, nanostructuring, hybrids, nanomaterials.

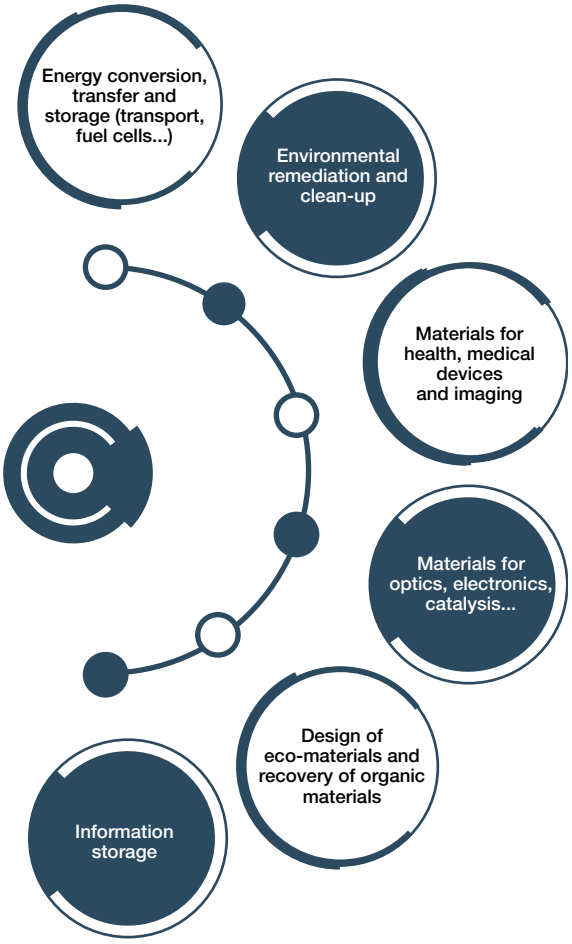
2

Advanced materials: application to energy, environment, sustainable development, health.

3

Modelling: structures, properties and reactivity of molecules and materials.

AREAS OF USE



AREAS OF RESEARCH AND EXPERTISE

• Elaboration of molecular architectures, complex nanomaterials, supramolecular, inorganic functional multiscale materials, porous hybrid materials, extended networks.

• Instrumental and methodological development for in situ, ex situ and operando studies and characterisations of the thermal, electro-chemical, magnetic, structural, vibrational, ionic or electrical conduction properties of materials.

• Design of devices and methods for assessing the performance of materials.

• Formulation and shaping of polymers.

• New ways of developing and optimising the performance of environmentally friendly materials and green chemistry (organocatalysis, low-energy activation, use of clean solvents, mechanochemistry).

• Study of material properties and optimisation of interaction at interfaces (solid/solid, solid/liquid, solid/gas or triple), with the surrounding environment, under specific operating conditions/constraints or application contexts.

• Synthesis, formulation and shaping of materials for energy: chalcogenides and glasses, crystals, nanostructures, oxide and hybrid materials.

• Electrochemistry for power.

• Theoretical physical chemistry at the scale of the molecule, nanoparticles, solids or interfaces.

• Theoretical physical chemistry for the methodological development of environmental physical chemistry, homogeneous and heterogeneous catalysis.

• Multi-scale modelling, suitable for investigating properties to guide experimental research towards a more rational design of new materials for target applications.

RESEARCH TEAMS

Department of Chemistry of Materials, Nanostructures, Materials for Energy

Department of Hybrid & Porous Materials

Department of Macromolecular Chemistry and Materials

Department of Molecular Chemistry and Materials

Department of Theoretical Physical Chemistry and Modelling

The Marcoule Institute for Separation Chemistry

At the interface between chemistry & physical chemistry

Date and context of creation: Founded in January 2005, as recommended by the French Academy of Sciences, in order to create a laboratory in France dedicated to research on the hydrometallurgical processes necessary for material recycling, the ICSM was founded and directed by Professor Thomas Zemb (INSTN, CEA/DRF). Initially applied to the nuclear fuel cycle, the ICSM's research also works on the separation chemistry of materials.

Director: Dr. Stéphane Pellet-Rostaing since January 2013

Number of employees: 100 people (45 permanent and 50 temporary)

Label : UMR 5257

Tutelles: CEA/CNRS/UM/ENSCM

8 research teams
450 publications - 33 patents of which 7 licensed in 5 years
98 contracts with private companies - 3 CIFRE supports in 5 years

Keywords
Sustainable nuclear energy, material economy, actinide chemistry, interface chemistry, ion separation, sonochemistry, nanomaterials, physical-chemistry non-conventional solvent.

As part of the Chemistry Research Department and the Institute of Sciences and Technologies for a Circular Economy of Low-Carbon Energies (ISEC) of the CEA's Energy Directorate (CEA/DES), the ICSM is thus in a unique position in France, if not in Europe, in the field of separation chemistry for the nuclear industry, the circular economy, processes and materials. It thus develops research from the most fundamental to the most applied.

MAIN RESEARCH AREAS

Optimisation of materials life cycle for energy

Innovation in extraction and recycling

Methodologies and theories in separation chemistry

AREAS OF RESEARCH AND EXPERTISE

1) Nuclear fuel cycle

Upstream of Cycle

• Understand and predict the separation phenomena of an ore containing uranium.

• Development of new organic and/or hybrid functionalized supports for a selective extraction of uranium.

• Synthesis of new extraction systems (liquid/liquid and liquid/solid) for a better understanding of the mechanisms involved in uranium extraction.

• Study of specific synergistic systems by molecular engineering (molecular clamps for selectivity, supramolecular cooperative phenomena).

Downstream of Cycle

• Study of the mechanisms of spent fuel dissolution.

• Development of new molecular and supramolecular actinide structures, organometallic networks or molecular clusters via co-precipitation process (oxalic, hydroxide...) via colloidal sol-gel approach and activated methods (sonochemistry).

• Optimisation of synthesis routes for mastering durability of the resulting powders.

• «Sustainable» nuclear cycle with the design of new routes for the synthesis and conversion of actinide materials directly from the separation step.

• Optimisation of complexing agents for the reprocessing of spent nuclear fuel and the separation of elements of interest (actinides, reusable and final waste).

• Development of theoretical and experimental approaches for liquid-liquid extraction in complex fluids and for the study of molecular and supramolecular extraction mechanisms.

• Physico-chemical studies of solid/liquid and liquid/liquid interfaces where ion exchanges, ion transfers and complexation reactions take place using radiation reflectivity and/or (non-)linear optics techniques.

• Development of original tools for in situ or operando (temperature, pH), observation and characterisation methods (including dilatometry, SEM in environmental mode...), construction of sintering maps of different oxides.

• Predictive models for optimisation of extraction process by development of multi-scaled modelling.

• Theoretical chemistry applied to molecular transfer/transport (liquid/liquid, liquid/solid phenomena) irradiation phenomena in confined structures.

2) Recycling and decontamination for a sustainable circular economy

• Innovation in methods, processes and eco-technologies for the recovery of high-purity noble and strategic metals.

• Short and green cycles for materials recycling from manufacturing scraps, waste or the processing of more complex objects at the end of their life.

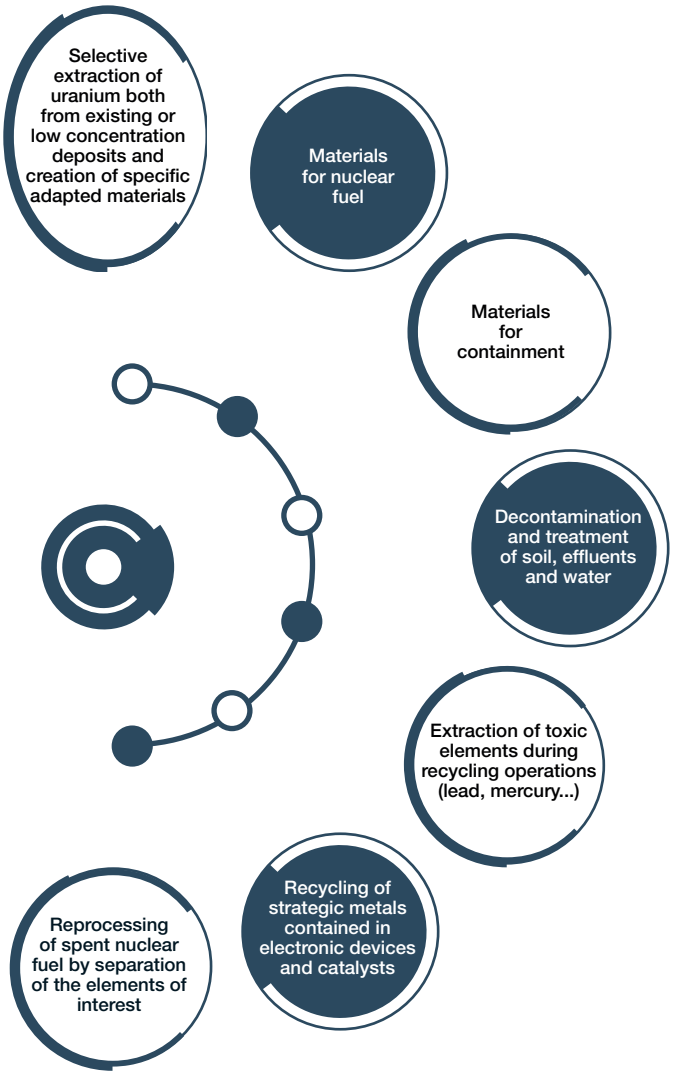
• Development of extractant systems and processes for the decontamination of soils with toxic metals (Pb, Cd, Hg, As, Ni...).

• Development of innovative processes for the purification of contaminated effluents (radio-, eco- or chemotoxic) by activation methods including sonochemistry.

• Study of (de)sorption mechanisms at the solid/liquid interface.

• Development of new ways of decontaminating liquid effluents (ion flotation).

AREAS OF USE



RESEARCH TEAMS

Targeted research laboratories:
Team 1 - Hybrid Systems for Separation chemistry (LHYS)
Team 2 - Ions at Active Interfaces (L2IA)
Team 3 - Ion Separation by Self-Assembled Molecular Systems (LTSM)
Team 4 - Sonochemistry in Complex Fluids (LSFC)
Team 5 - Adaptive Nanomaterials for Energy
Team 6 - Evolving Material Surfaces (LIME)

Intersecting research teams:
Team 7 - Environmental Microscopy (L2ME)
Team 8 - Mesoscopic Modelling and Theoretical Chemistry (LMCT)

The European Membrane Institute

At the interface between chemistry, process engineering & engineering sciences

Date and context of creation: The IEM was founded in 2000 under the leadership of Professor Louis Cot in order to develop an international reference laboratory in the field of membrane materials and processes in both France and Europe.

Director: Pr. David Cornu, since 2021

Number of employees: 75 permanent and ~ 100 temporary

Label : UMR 5635

Tutelles: CNRS/ENSCM/UM

Keywords
Membrane materials, development of innovative processes, pollution control, energy production and transfer, biotechnologies, food and health.

3 scientific departments
973 publications - 21 patents in 5 years
58 contracts with private companies - 9 CIFRE supports in 6 years

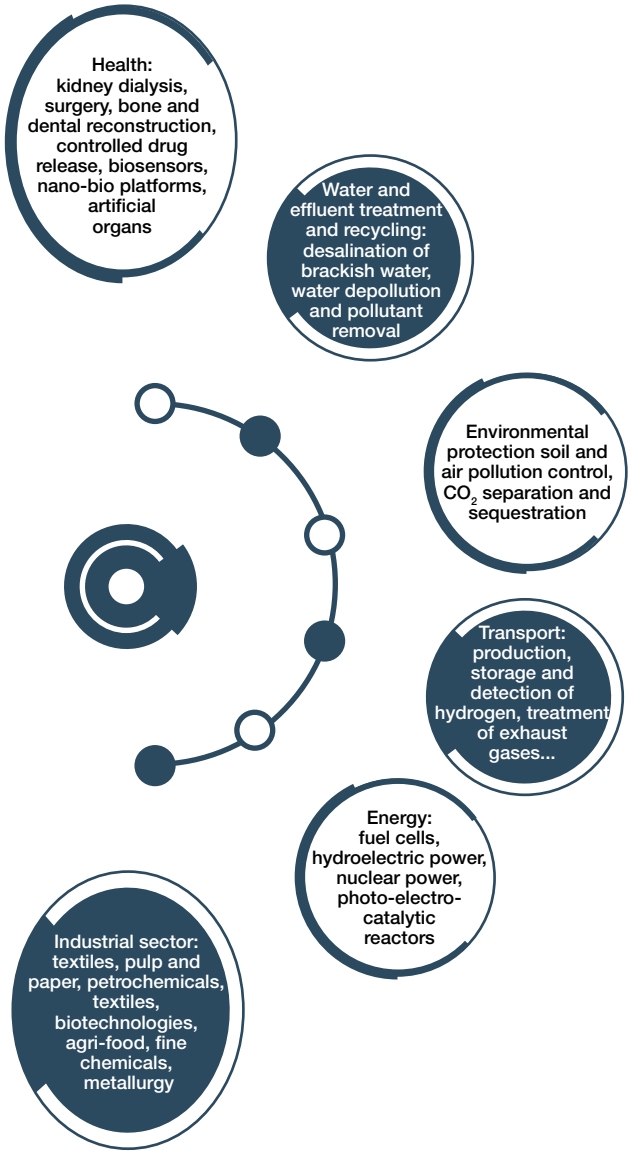
The objective of the IEM is to develop membranes and membrane processes capable of separating or diffusing entities efficiently to solve numerous questions in the fields of the environment, energy and water treatment. The IEM therefore calls for specific and complementary skills in order to conduct multidisciplinary researches.

MAIN RESEARCH AREAS

1. **Design and development of functional or nanostructured materials** with hierarchical structure and controlled porosity in specific configurations and morphologies.
2. **Study and control of interactions between the membrane surface**, the environment and the solutes to be separated, using ex situ, in situ and operando characterisation techniques.
3. **Determination of physico-chemical and hydrodynamic** operating conditions that optimise transport and transfer phenomena (of matter or heat).
4. **Development of process and membrane engineering approach** to model the design of membrane materials and systems.
5. **Develop high efficiency membrane modules.**
6. **Change of scale from laboratory object to the pre- or semi-industrial module.**

Membrane technologies are a strategic economic sector in particular in the areas of energy, environment and health. These areas are the main scientific focus of the IEM and also contribute to the clear inclusion of the Chemistry Department's research in an integrated societal research approach. In particular, membrane technologies are considered dominant technologies in many industrialised countries today and for the future economy. The sector is extremely dynamic and is in particular in need of innovative research and training tools.

AREAS OF USE



The unit's scientific project is developed around major societal concerns, making it possible to clearly target the applications around which the unit is positioned. The IEM is thus structured into three scientific departments with complementary skills. To implement innovative and integrative research projects, the unit relies on two major scientific ambitions called transversal axes:

• Transverse axis «Energy and Micro-Energy» concerns both research on membrane materials and the development of innovative methods and processes useful for energy conversion.

• Transverse axis «Water» focused on membrane solutions and process coupling to improve the reliability of secondary water production (treated waste water or brackish water) and the detection by biological indicators and elimination of emerging pollutants.

AREAS OF RESEARCH AND EXPERTISE

• Development of synthesis and association of molecules, by supramolecular chemistry, soft chemistry, polymer derived ceramics, chemical vapor deposition, atomic layer deposition, exfoliation and electrospinning.

• Elaboration and characterisation of bioinspired and biosourced polymer membranes, carbonaceous and metallic materials, ceramics (and their precursors), supramolecular nano-systems, nano-composites/nano-hybrids.

• Development of bioinspired interfaces (surface chemistry, physical chemistry and biophysics), ionics and electrochemistry (physical chemistry, interfacial electrochemistry, electrocatalysis and vibrational spectroscopies) and in macromolecular materials (polymer chemistry and physical chemistry).

• Studies of structural, physico-chemical, electro-chemical and usage properties of membrane materials integrated in (multi)functional systems, of nanostructured interfaces (spectroscopic, electro-chemical...) and of nano-materials or the monitoring of operando membranes.

• Development of innovative characterisation methods for the study of the porous texture of thin films, tools relating to effluents, membranes or also developed on line and in situ, allowing the quantification of transfer and reaction rates and the validation of mathematical models.

• Development and optimisation of hybrid and/or multi-functional membrane processes and laboratory experimental systems of different scales to analyse and quantify the performance of membrane materials within processes.

• Development of modelling tools to simulate the dynamics of morphogenesis on the scale of a membrane under development, coupled transfer phenomena (matter, heat) on the scale of a membrane module.

RESEARCH TEAMS

DM3 team: Design of Membrane Materials and Multifunctional Systems

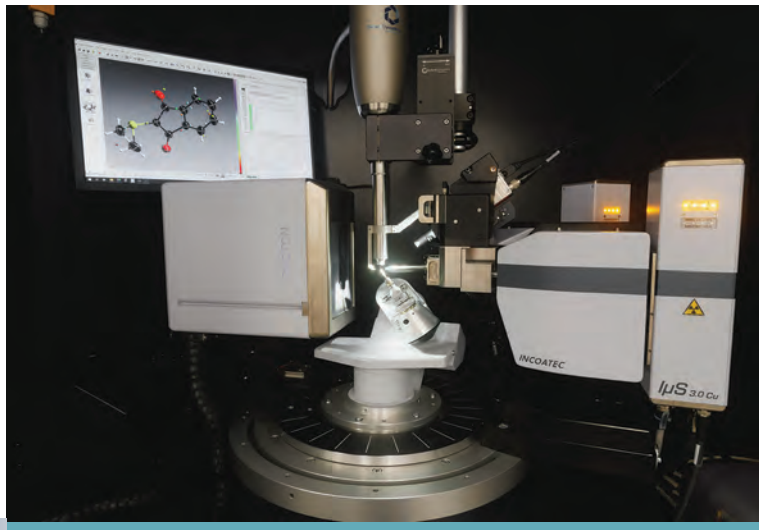
GPM team: Membrane Process Engineering

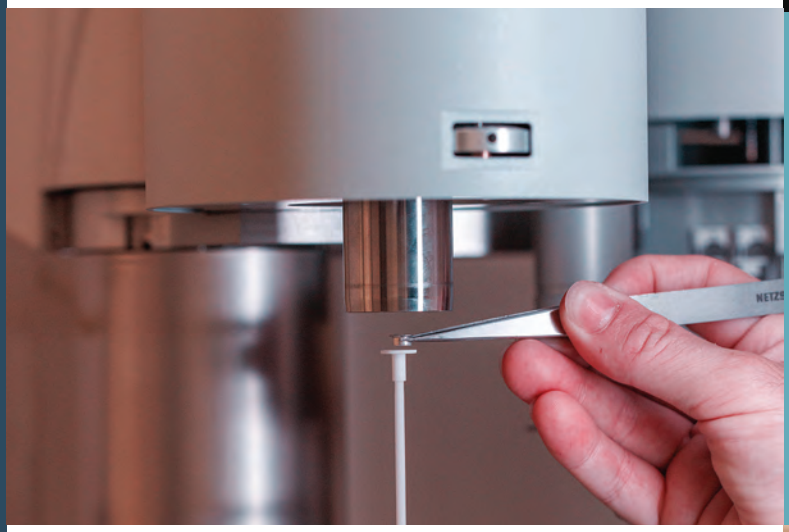
IP2 team: Interfaces, Physical chemistry, Polymers

2. Technical and Service Platforms

PAC, ChemLab, Synbio3

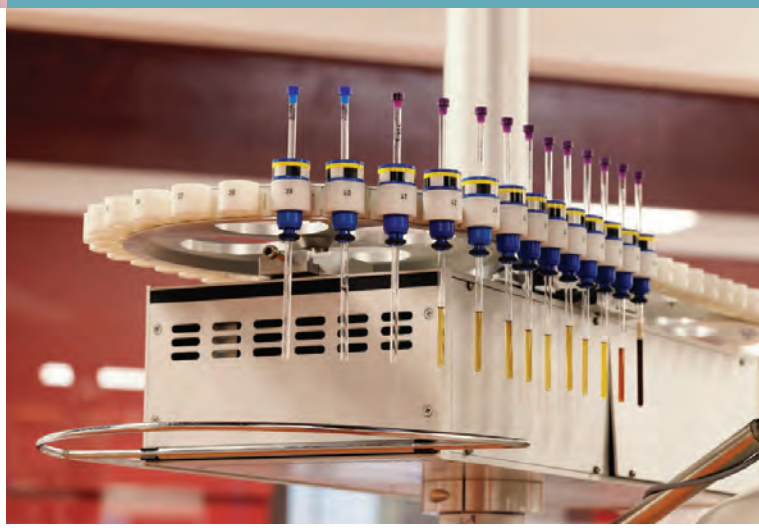
Heavy and medium-heavy equipment for synthesis, processing and characterisation in chemical and materials science.





A unique academic and industry-oriented technological platforms, available on the same site.

Support & expertise of highly qualified technical and academic staff.



PLATEFORMES
CHIMIE BALARD

Analysis and Characterisation platform, PAC
From molecular to macroscopic

Keywords: Taylored analytical solutions, from materials chemistry to biomolecules, environment and health. From the simple handling of samples and analytical services to the development of complex research methodologies.

Location: Ground Floor Balard Recherche Building
Surface Area: 1,800m²
Number of employees: 20 full-time FTEs
Certification : ISO 9001 for 4 of the 11 services
11 analysis services
50,000 analyses/year

The high-tech instrumental equipment, valued at more than €15 million, includes nearly fifty pieces of state-of-the-art equipment and offers a wide range of analytical and characterisation techniques open to the entire academic and industrial community. These instruments and skills cover materials, organic molecules and biomolecules, either synthesised or present in biological media.

EQUIPEMENTS

- 11 NMR spectrometers (solid, liquid and HRMAS)
- 6 mass spectrometers
- 6 ^{57}Fe and ^{119}Sn Mössbauer spectrometers (2 at variable temperature)
- IR-Raman spectrometers
- A fleet of diffractometers (7 for the analysis of powders, single crystals and thin films)
- Dielectric measuring equipment (TSC, SIC)
- SQUID magnetometers and EPR spectrometer
- Chemical analysis (elemental analysis, ICPMS or X-ray fluorescence spectroscopy)
- Thermal and calorimetric analysis equipment (a total of 6 DSC, ATG-DSC-MS, ITC, SolCal, immersion and gas flow calorimeters)
- A X-ray photoelectron spectrometer, the only equipment of this kind in the Montpellier research area.
- Textural, granulometric or surface reactivity analyses
- Scanning and transmission of electron microscopes

COLLABORATIONS & IMPLICATIONS IN R&D

- Analysis of residual pesticides detected on mosquitoes in the framework of an environmental research project led by IRD Occitanie.
- Interdisciplinary project «Mutations alimentaires» funded by the CNRS, to optimise active packaging materials for food preservation.
- A research project in partnership between the local company Deinove and IBMM has just been financed by the Occitanie Region and Europe (ERDF, 1.2M€ over 30 months) to discover new compounds for antibiotic use.
- ERC project dedicated to the development of advanced analytical tools based on solid state NMR spectroscopy.
- MOPGA project for the development of innovative materials for air purification.
- Continuous methodological developments with IBMM and ICGM, with a regular publication activity resulting from the work with the PAC.

A dynamic policy of acquisition and renewal of strategic PAC facilities has recently been implemented (CPER program) and ensures a wide coverage of top-of-the-range analytical services, positioning the PAC very favourably at regional and national levels. Its attractiveness towards academic and private partners (start-ups, SMEs, national and international companies) is the result of the availability of high-performance, high-tech tools combined with the expertise of the technical staff of the various services and the scientific support of the researchers of the Chemistry Research Department. It provides major support to academic players, resulting in about 50 publications per year. Several collaborative and innovative research projects related to I-SITE's societal issues of «feed, protect and care» have been initiated in recent times thanks to the combination of a wide range of techniques and expertise available to support academic and industrial research.

PLATEFORMES
CHIMIE BALARD

ChemLab platform

From the lab to large scale production

Keywords: Fine organic chemistry, pharmaceuticals, cosmetics, agrochemicals, polymers, extraction of natural active ingredients

Location: ENSCM

Surface Area: 372m²

Number of employees: 2 full-time FTEs

ChemLab is a platform of technological equipment and scientific skills for public laboratories and companies. It offers chemical synthesis and plant extraction services from the development phase through to production.

CONTEXT OF CREATION

In 1992, the Bristol-Myers Squibb company decided to close the Montpellier R&D centre and handed over its site to ENSCM for industrial piloting, thus providing it with a real high-performance industrial teaching tool: the Process Engineering Unit (UGDP).

In 2014, following the evolution of its activity, the UGDP became the current ChemLab™ platform. In 2017, following the relocation of the ENSCM on avenue Emile Jeanbrau, ChemLab moved to new premises on the «Pôle Chimie Balard» campus, fully equipped. The ChemLab platform has kilolab or pilot scale facilities, unique in France at the academic level. Run by a permanent officers, the team is qualified in fine organic chemistry, extraction of natural active ingredients and trained to industrial constraints. ChemLab works closely under confidentiality agreements with the research units of public laboratories and with various national and international fine chemicals companies (pharmaceuticals, cosmetics, agrochemicals, polymers).

MISSIONS & SERVICES

• Analytical monitoring in the context of custom synthesis or industrial partnerships in the form of service provision or research collaboration contracts.

• Writing of bibliographic reports, development of industrial processes, development, extrapolation and optimisation of synthesis or extraction.

• Support for innovation, particularly of local SMEs and start-ups, with almost all of its turnover generated with companies (€173k in 2016).

• Tool at the service of pedagogy through practical work on industrial equipment, support for entrepreneurship projects of students in the final year of the engineering cycle (EPIIC project, MUSE funding).

EQUIPMENT

• Explosion-proof workshop equipped with 10L and 20L glass jacketed reactors to validate the laboratory process and a 60L glass reactor with enamelled bottom to synthesise the first development batches (Treatment by filter press, bell or Nutsche, wringer - Decanter, grinder, vacuum ovens - Vacuum distillation column - Fluids: glycol, steam, demineralised water, compressed air, nitrogen, argon).

• Extraction laboratory equipped with a microwave reactor for synthesis (batch up to 3L or continuous) and extraction (industrialisable equipment) and an ultrasonic assisted extraction reactor up to 3L.

• Synthesis laboratory for the development of synthetic reaction steps.

• Analysis laboratory: GC, HPLC, IR, UV, NMR, Karl Fischer, titrimetry, polarimeter, refractometer.

All fine organic chemistry reactions in the temperature range of -27°C to +150°C can be carried out in the workshop, usually at atmospheric pressure, in homogeneous or heterogeneous conditions. It also carries out the extraction of natural active ingredients, particularly from algae.

WORKING METHODS

• Quality and Safety
• Experience in BPF, BPL and GMP practice.
• A set of procedures written for each operation to ensure safe and reliable processes and a consistent level of quality.
• Documents attached to the finished products: batch record and certificate of analysis.
• Confidentiality by secrecy agreement.
• Production of batches from 1g to 50kg per batch.

COLLABORATIONS & IMPLICATIONS OF CHEMLAB:

The platform regularly participates in scientific events such as the «Journées Carnot Institute Chemistry Balard Cirimat» and the SIRIC Montpellier Cancer days in order to present its activity and prospects for new clients or new partners.

ChemLab has already been solicited as a partner via calls for projects financed by public bodies, in particular to validate a rise in the TRL of the project or thanks to the innovative technologies with which the platform is equipped. At the end of 2019, ChemLab started to expand its activity and now provides support and expertise to public laboratories on collaborative projects which has enabled the publication of results in 2020.

As part of an agreement between the CNRS and the «Fédération nationale des dispositifs de ressources et d'appui à la coordination des parcours en santé» (Facs), ChemLab was called upon during the COVID-19 pandemic to produce hydroalcoholic solution on a large scale for city carers and home helps. In total, more than 3000L of solution was produced and distributed free of charge.

PLATEFORMES
CHIMIE BALARD

Synthesis of Biomolecules for Biology and Biotechnology Platform, Synbio3

A key partner in life sciences to develop new biomolecules & polymers

Keywords: Biology, chemistry, pharmacology, biomolecules, polymers
Date of creation: 2007
Location: Bâtiment Balard Recherche
Surface Area: 1,800m²
Number of employees: 4 FTE (2 technicians/3 design engineers/2 research engineers)
IBiSa : approved since 2013
Certification : ISO 9001 since 2015

CONTEXT OF CREATION

SynBio3 platform was created at the IBMM, which is recognised worldwide for its expertise at the interface between chemistry and biology. It is this commitment to interdisciplinarity that has enabled IBMM to design two drugs (Telbivudine and Macrilen), which were put on the market in 2010 and 2018 respectively, and which motivated the creation of SynBio3.

SynBio3 supports any research project, whether academic or industrial, by providing useful scientific expertise and original and concrete solutions to their scientific problems relating to the synthesis of biomolecules and polymers of biological and pharmaceutical interest.

The platform is made up of a «Peptide» platform and a «Polymer» platform attached to the teams of «Amino Acids, Heterocyles, Peptides and Proteins» and « Polymers for Health and Materials» of IBMM respectively. Its regularly renewed equipment, estimated at €550,000, guarantees the reliability and performance of its scientific expertise and contributes to SynBio3's attractiveness. In the field of health polymers, the equipment allows the synthesis of batches on a scale of approximately ten grams, which is perfectly suited to the phases that precede an industrial scale-up.

Its expertise in the design of bioactive molecules and polymers enables it to guide, advise and support teams of biologists and industrialists in their projects. In many cases, SynBio3 acts as a springboard to unlock a lock or deliver a proof of concept and subsequently enable collaborative research projects to be set up.

Since its IBiSa accreditation, SynBio3 has contributed to more than 132 projects, including 41 for teams from the Chemistry Research Department, 46 for industrialists, and 45 for collaborative projects at the interface of biology and chemistry. It should be noted that three-quarters of the users come from the local community, composed mainly of SMEs, start-ups and public laboratories (university hospitals, research institutes).

EQUIPMENT

• 1 microwave irradiation assisted peptide synthesizer (Liberty, CEM)

• 1 parallel peptide synthesizer (Multipep, CEM)

• 2 preparative liquid chromatography purification systems (Gilson Armen)

• 3 UPLC/MS instruments for classification (Agilent 1260 and Waters Acquity)

• 1 circular dichroism spectrophotometer (JASCO)

• 1 Multi-angle dynamic light scattering equipement (Zetasizer Ultra, Malvern)

• 1 large capacity freeze dryer (CryoNext) for drying products

• 1 refrigerated cabinet for chemical library (Accsa'tech) for conservation of end products at -20°C

• Dedicated ladder climbing equipment (from 1 to 10g):
- 1 preparatory HPLC of the pre-industrial type (Gilson).
- 1 10L rotary evaporator (Büchi).
- 1 analytical HPLC (Agilent 1260).

• Polymeric tray equipment for scaling up (from 10 to 100g):
- Equipment for the synthesis of polymers in the molten state (polymerisation oven).
- Equipment for the synthesis of polymers insolution (reactors, Schlenk tubes...).

• Polymer classification equipment:
- Chains of steric exclusion chromatography (Shimadzu) under different conditions and solvents.
- Thermal analysis equipment such as differential scanning calorimetry (DSC, Mettler Toledo).
- Thermogravimetric analysis (TGA, Mettler Toledo).
- Capillary ball viscometer (Anton Parr Lovis 2000 ME).
- A Karl Fisher coulometric titrator (Mettler Toledo C10 SX).
- An IR-TF spectrometer (Perkin Elmer Spectrum 100 Serie).

COLLABORATIONS & IMPLICATIONS IN R&D:

• Support for a collaborative research project in the development of an innovative treatment for rare diseases of premature ageing with the company ProGeLife.

• Support for the research project in the field of oncology and bacterial infections in veterinary therapy with the company Panvir Therapeutics.

• Montpellier-based company MedinCell for the manufacture of resorbable polymers for the controlled release of active ingredients.

• First FindMed contract with Orphelia Pharma, which enabled the company to market Kigabeq® for the treatment of resistant partial epilepsy in children in Germany.

• Contributes to the development of several topics with teams from the Montpellier Cancer Research Institute (IRCM) for the preparation of specific biomarkers or the production of monoclonal antibodies.

• ARC and INCa projects for the preparation of targeting and imaging agents.

• Methodological development with IBMM, 28 publications have resulted from work with SynBio3 over the last 5 years, 2015-2020.

3. LabUM Chemistry / LabEx CheMISyst

Its laboratory of excellence, a tool for innovation in research

Director: Dr. Stéphane Pellet-Rostaing
Workforce: composed by IBMM, ICGM, ICSM, IEM

CONTEXT OF CREATION

The LabUM Chemistry is an exploratory and thematic laboratory of the University of Montpellier, which continues the transversal research undertook by the laboratory of excellence (LabEx CheMISyst, Chemistry of Molecular and Interfacial Systems) following the cessation of its activities.

LabUM Chemistry aims to financially support the training and disruptive research on a future-oriented theme: the science of «adaptive materials and complex molecules». The aim is to study, control and create novel, complex, biomimetic molecular systems with applications related to the three pillars: «feed, protect and care».

ITS MISSIONS

• To support the work of the research teams from the Chemistry Research Department's four institutes (Budget 08/2020-12/2021: €1million).

• To explore the diversity of scientific skills and the multidisciplinarity of its teams in order to promote innovation in research and the synergy of research activities between the different disciplines of the University, the I-SITE programmes and its partners.

• To promote research-training links.

• To strengthen scientific development.

Key figures of LabEx CheMISyst / LabMUSE Chemistry 2011 - 2022

9.1 M € total budget
1,8 M € for state-of-the-art equipment
4 startups created
12,8 M€ leverage
243 scientific publications
≥20 Patents

1 Academic Chair
80 research programmes supported
38 Doctoral Fellowships
42 Postdoctoral Fellowships
108 Funded Master Internships
12 Visiting Professors

9 Summer Schools
1 Specialised online course «SPOC Recycling Chemistry
72 thematic scientific events and workshops
5 "Balard Conferences" events

The work carried out by LabUM Chemistry/LabEx CheMISyst enables progress to be made in the understanding of physico-chemical mechanisms for more selective targeting and more effective vectorisation of adaptive systems for health, optimisation of innovative separation and recycling methods, and better control of the properties of materials for energy.

4. The Carnot Institute

A label, to the promote partnerships

Created in 2006, the Carnot label aims to develop partnership research, i.e. research carried out by public laboratories in partnership with socio-economic actors, mainly companies (from SMEs to large groups), in response to their needs. Partnership research is an important lever for the economy by encouraging business innovation, guaranteed competition and growth.

The Carnot Institute Chemistry Balard Cirimat presented below is a partnership research structure labelled «Chemistry, Environment, Sustainable Development» in 2007 by the Ministry of Higher Education, Research and Innovation. So any company interested in collaborating with an academic research partner or in accessing technical or technological platforms can contact the Carnot Institute Chemistry Balard Cirimat which will help it to define its needs and put it in touch with the most relevant research team or platform.

INSTITUT CARNOT Chimie Balard Cirimat

The Carnot Institute Chemistry Balard Cirimat

Date of creation: 2006
Director: Pr. Yannick Guari
Workforce: composed by IBMM, ICGM, ICSM, IEM and CIRIMAT (from Toulouse) 800 researchers and non-permanent staff, including 320 PhD students, 27 of whom are CIFRE (Convention Industrielle de Formation par la Recherche)
Tutelles: CNRS/ENSCM/INP Toulouse/University of Montpellier/University Paul Sabatier, Toulouse

The Carnot Institute Chemistry Balard Cirimat develops innovative solutions in strategic fields and contributes to the competitiveness of companies from the very small to the large. It generates nearly €14 million in partnership revenue per year. The scientific production of its researchers amounts to 900 rank A publications per year, and ranks it 4th in terms of patent filings in Occitania, behind the major industrial groups Airbus, Continental, and Safran.

MULTIDISCIPLINARY RESEARCH & DEVELOPMENT AREAS

1

Energy: new fuels, fuel cells, hydrogen carrier, electrochemical storage and energy conversion, structural materials for nuclear devices.

2

Health and Cosmetics: drugs, pharmacological tools, biomaterials, vectorization, medical devices.

3

Materials for transport (aeronautics, space, rail, automotive): structural materials, coatings, components.

4

High performance materials: metals, alloys, ceramics and polymers, manufacturing processes, nanomaterials, durability.

5

Sustainable Chemistry and Processes: substitution of dangerous compounds and metals, alternative solvents, mechanochemistry, recovery of biomass, waste and co-products from synthesis.

ITS MISSIONS

- To create a favourable environment for translating basic research results into technological applications.
- To support resourcing actions on its five research themes that are strongly linked to major societal challenges.
- To promote partnership research and the development of business competitiveness through innovation.
- To contribute to the maintenance and further growth of employment in the region and nationally, with a particular focus on small businesses (VSEs, SMEs and SMIs).

5. The range of training courses

The University of Montpellier 6th in France - 50,000 students

The transmission of knowledge is at the heart of the Chemistry Research Department's missions and is a priority. The training courses are closely linked to research topics of the Chemistry Research Department's institutes. Thus, it covers the entire spectrum of chemistry at the interface between biology, health, physics and ecology, offering to students an access to vast choice of courses.

This proximity with research is a great opportunity for students to be involved in technical, technological, scientific innovations but also in educational innovations (virtual reality, peer-to-peer instruction, escape games, serious games...). The teaching teams and staff of the Chemistry Research and Training Departments are supporting the success of students throughout their studies. Interdisciplinary courses, both theoretical and practical, also allow students to acquire a global vision of research that is attuned to the complex challenges of a science at the interfaces that serves humankind and respects the environment.

In addition to the acquisition of knowledge and skills, they implement variety of actions in favour of innovation for supervision, support, follow-up, teaching, mentoring, professional integration, support for entrepreneurial projects and career change of students who so wish.

Doctoral students from all over the world are joining each year our laboratories, who are attracted by the excellent research and teaching provided by our highly qualified experts. Training courses, workshops on various themes (entrepreneurship, CV development, mastery of digital scientific information and communication tools, scientific integrity...), internships abroad, international conferences and events punctuate their curriculum in order to train the future generations of scientists and entrepreneurs.

This section will present the entire training offer followed by more than 2,000 students from professional and engineering degree to the doctorate of the University of Montpellier and the National Graduate School of Montpellier.

Training institutions

- IUT Montpellier Séte
- Faculty of Sciences
- National graduate of chemistry of Montpellier

Doctoral school

- Balard Chemical Sciences ED459

IUT of Chemistry Montpellier-Sète

Date of creation: 1966/ ±4000 graduates in 50 years
Director of IUT: Matteo Valenza
Workforce: 400 students/35 teachers
Certification: ISO 9001 version 2015
Rate of employment at 6 months after graduation: 75%
Rate of employment after professional bachelor: 90%
ECTS: 120 or 180

The IUT of Chemistry provides both theoretical and practical education, with the main objective of training senior technicians, direct collaborators with engineers or researchers in all areas of chemical applications: research, development, production, analysis or control. In addition to the DUT and the University Bachelor of Technology (BUT), it offers 4 professional qualifications.

Thanks to its close links between research institutes and with the professional world, the IUT is constantly seeking to enrich and update the training of its students in order to train them for today's world.

This effort of adjustment concerns, on the one hand, the teaching, whose learning techniques must be adapted to an environment where the place of digital technology is preponderant and, on the other hand, by proposing the use of digital equipment allowing students to acquire the mastery of innovative technological tools, which are more and more present in the industrial fabric.

In this context, the creation of a digital manufacturing space, inspired by the international network of Fab Labs, was initiated in 2017 within the campus of the IUT Montpellier-Sète: Ob.i LAB. The Ob.iLAB space, allows students to bring projects from idea to implementation and to have the pride of being able to carry them out or with others. It is designed for all the students and staff from all the courses of study at the IUT Montpellier-Sète.

IUT'S PRIORITIES

• The development of quality training with ever more efficient technological means: renewal of teaching materials, modernisation of technical platforms to keep up with technological innovations.

• Opening up to the business world. Creation of a technology hub and a collaborative workspace accessible to students and companies wishing to work in partnership with the IUT. Annual organisation of an IUT-Enterprise forum during which companies can propose their internship offers and meet students. Organisation of business creation competition. We have a policy of developing work-study programmes, 13% of our students are on work-study programmes.

• Opening up to the international market. We have developed an extensive network of international partner universities and companies. Students who wish to do so can do internships or further studies abroad.

DEPARTMENT OF CHEMISTRY - MONTPELLIER

List of courses

• B.U.T., Bachelor of Technology in Chemistry (level Bac+3); 3 Study tracks :

1/ Analysis, quality-control, environment:
Graduates will be able to carry out every step of an analytical process, from sampling and product pre-treatment through to the implementation of the analytical method, optimisation and validation.

2/ Synthesis : Graduates will master the various methods of synthesis, purification and characterisation of organic or inorganic compounds, the setting up of a synthetic route and implementation of the experimental protocol (multi-stage synthesis, separation techniques for product purification, micromanipulation and gram-scale experiments, catalysis) in organic and/or inorganic chemistry.

3/ Materials and formulated products :
Graduates will be able to carry out every stage of the processing of materials or formulated products: from the selection of raw materials through to conception, product identification and physico-chemical characterisation of materials and end products.

• Professional Degree in Chemistry of materials: Polymers for industry and the environment

• Professional Degree in Chemistry of materials: Chemistry and processes applied to nuclear fuel

DEPARTMENT OF CHEMISTRY - SÈTE

It offers teaching on the environment with a focus on environmental chemical analysis. This specific course deals with current topics such as air, water and soil pollution, waste treatment, rehabilitation of polluted sites, sampling techniques and field analysis.

List of courses

• D.U.T., Diploma of Technology Chemistry (Bac+2 level) analytical and synthetic chemistry Orientation: Chemical analysis applied to the environment.

• B.U.T, Bachelor of Technology specialising in Chemistry, «Analysis, Quality Control, Environment» (level Bac +3), with a focus on environmental chemistry:

1/ Professional Degree in Analytical Chemistry, Control, Quality and Environment : Chemical analysis applied to the environment (ACAE).

2/ Professional bachelor's degree in environmental process engineering:
Automated Management of Water Treatment Systems (GASTE).

JOBS & CAREERS

These diplomas give access to all sectors of the chemical and processing industries (heavy and fine chemicals, pharmaceuticals, food processing, materials, ceramic manufacturing, metallurgy, cosmetics, metal, dye, rubber or plastic productions, nuclear, automotive, waste processing, surface treatment...) as well as in the public sector:

• University research laboratory or in industry laboratories (research, fine chemistry, organic or inorganic synthesis, analysis, quality control, industrial development).

• Workshops (production, pilot).

• Services (technical-commercial, security, administrative, training).

• Further studies in engineering schools, doctorate.

Faculty of Sciences

Within the Faculty of Sciences of the University of Montpellier, the Teaching Department of Chemistry offers several courses at Bachelor and Master's degree level.

The Bachelor's degree in Chemistry

Number of students: ±350 (L1 to L3)
Master's degree continuation rate: 80%
with 70% of them have a Montpellier Bachelor degree
Duration: 3 years
ECTS: 180

It offers a generalist education, allowing the acquisition of fundamental theoretical and experimental knowledge in Chemistry: general, inorganic, organic, macromolecular, spectroscopic, and analytical, with a progressive specialisation in L3 (3rd year) towards the fields of the chemical sciences of living world or the chemistry of materials.

List of courses

• The Chemical Sciences of the Living World course (L3 SCV) is focused on organic chemistry with an approach towards biomolecular chemistry and the corresponding masters. This multidisciplinary course directs students to work in the fields of biomolecules, drugs, cosmetics, perfumes and fragrances.

• The Chemical Sciences of Matter course (L3 SCM) is a generalist training in inorganic chemistry, solid state chemistry and general and macromolecular chemistry. This course directs students towards the materials and polymer sectors with applications in the fields of nanosciences, coatings, energy and sustainable development.

Specific courses attached to the chemistry degree

• The L3 prepa DNO course is a course in the chemistry degree intended for students who want to acquire the «L3 es chemistry» required to enter oenology schools.

• The prePAC Perfumes and Cosmetics course (L2 PrePAC) is only accessible under certain conditions (limited number of places). This course allows students to enter the PAC «Perfume, Flavour and Cosmetics» professional degree in L3.

Objectives of the Bachelor

• Continuation of studies in a Master's degree in chemistry, in a Master's degree in health biology and preparation for the National Diploma in Oenology.

• Admission to engineering school (on title).

• Continuation of studies in a short professional course: integration of Professional Degree (Licence Pro).

• To allow direct professional integration at the end of L3: administrative competitions, technicians.

The Master's degree in Chemistry

Number of students: ±300
Appeal: 43% of students from outside UM
Success rate: 93% in M2
Employment rate 6 months after graduation: 86%
Duration: 2 years
ECTS: 120

It offers multidisciplinary training in chemistry at the interface between life sciences and materials sciences, enabling future graduates to acquire specific skills and knowledge in modern chemistry in order to be employed as managers or to begin a research activity through a doctorate.

This training is based on scientific excellence, which is recognised on a national and international level, of the research teams of the four research institutes of the Chemistry Research Department. It thus covers the three main themes of the Chemistry Research Department: materials and energy, chemistry for human health and well-being, and resource conservation and environmental protection.

This training is structured around seven M1 and M2 courses, namely:

1. Biomolecular chemistry
2. Theoretical chemistry and modelling
3. Cosmetic engineering
4. Flavour and Fragrance engineering
5. Materials chemistry
6. Separation chemistry, materials and processes
7. Material science exploring large scale facilities

Jobs & careers

• Chemical engineer, materials chemist, or process chemist in charge of production, analysis, quality control or project management.

• R&D engineer in a design office or in the chemical industry, pharmaceutical industry, health industry, recycling industry, environment, medical device industry, contrast agents.

• Product application manager, process engineering design manager, manufacturing manager, chemical analysis manager, analytical platform manager, process engineering specialist, industrial risk specialist.

• Researcher / R&D or research engineer (after a doctorate for which this course prepares): conducting scientific studies and setting up technological projects.

FACULTÉ DES SCIENCES DE MONTPELLIER

The Energy Master's degree

Number of students: 45
Employment rate 6 months after graduation: 60%
Employment rate 30 months after graduation: 95%
Duration: 2 years
ECTS: 120

Opened in 2011, this master is unique in the national training offer in the field of Energy, covering all the issues of the energy transition. This master involved lecturers from the Physics, EEA, Chemistry, Biology, Earth Sciences and Computer Science departments. The recruitment is also multidisciplinary, where the students who are joining this master are chemists, physicists, biologists and geologists.

The master offers 3 types of specialities:

1. EMSAR: Multi-source energy management, self-consumption and micro-grids, for initial training.

2. G2Sco: Energy Management, Sources, Storage and Conversion for initial training.

3. GREEN: Network Management and Renewable Energy, for professional training developed with a company, work-study, which includes training and apprenticeship in the industry.

Jobs & careers

The aim of the Energy Master's degree is to train cross-disciplinary project managers in the fields of energy, capable of answering the questions posed by local authorities and companies regarding the choice of resources and the management of the energy mix. It also aims to develop professionals able to manage the various research/development and/or organisational aspects of projects relating to network management, energy source and resource management, energy conversion and storage.

The IDIL Master's degree

Registration: Opened to international students
Language: English (written and spoken) French as a foreign language
Duration: 2 years
ECTS: 120

Launched in 2022, IDIL master degree promotes interdisciplinarity by developing a new training vision and research approach, which is based on 9 thematic topics situated at the crossroads of the Montpellier site. For chemistry, the course proposes is «Chemistry for Care, Protect and Feed».

Specially designed to train students aspiring to a scientific career in R&D, the master course in chemistry offers multidisciplinary training around chemistry, supplemented by biology and pharmaceutical sciences on one side and chemical engineering and material sciences on the other. It leads to in-depth and up-to-date training in molecular and macromolecular chemistry, and materials chemistry applied to health and the environment (from eco-design to recycling), combined with research training in its leading laboratories.

This master allows students to customise their programmes according to their professional projects by proposing:

• Training units (in chemistry and in other disciplines of the IDIL programme, methodological and professional training, workshops in the laboratory).

• Personal project and multi-disciplinary project mentored by researchers.

• 6-month internship in a research laboratory each year.

Jobs & careers

The aim of the IDIL Master's degree is to train students through and for research in collaboration with the research laboratories of the University of Montpellier, facilitating the continuity of the master graduate student to PhD level.

National graduate school of chemistry of Montpellier

Date of creation: 1920
Appeal: 100% of students come from outside ENSCM
Number of students: ~360 students (83% students and 17% apprentices)
Success rate: >98%
Employment rate after graduation: 93-100% from the last 4 years
ECTS: 180
Duration: 3 years
Certifications: by CTI (5 years maximum duration*) and by ISO 9001
Label: Apple Distinguished School

* ENSCM is allowed to deliver engineering diploma in chemistry by the Commission des Titres d'Ingénieur (CTI).

The ENSCM is the 2nd best National Graduate School of Chemistry in France which belongs to «French Grandes Ecoles». For more than 100 years, ENSCM offers a 3-year Engineer Degree Program and ensures graduation to high-level, multi-skilled generalist chemical engineers and managers to fulfil the needs of the chemical industry. ENSCM trainings combine scientific knowledge with interpersonal skills, giving students a broad scientific background in chemistry, engineering and social sciences. The scholarship is also opened to apprenticeship.

List of courses

The programme of study is designed to acquire well-balanced theoretical and practical experiences. The main professional areas covered by the ENSCM belongs to Chemistry – Health and Chemistry – Materials – Environment, which in the fifth academic year are declined into 7 graduate majors in line with the industrial needs and societal and environmental challenges.

Chemistry - Health

Chemistry and health majors offers training focused on health field based on organic chemistry (synthesis of compounds with medicinal therapeutic interests), biology (molecular approach of biological phenomena) and chemical engineering (processes involved in the production of a drug or a cosmetic product) through 3 following graduate majors:

- Fine organic chemistry,
- Chemistry biology health,
- Active natural ingredient engineering.

Chemistry - Materials - Environment

Chemistry-Materials-Environment majors are based on materials chemistry (polymers and inorganic materials), the study, protection and restoration of the environment, the use of renewable and sustainable resources for the replacement of fossil carbon, and the nuclear cycle through 4 following graduate majors:

- Chemistry of materials
- Environmental management and pollution remediation,
- Chemistry and bioprocesses for sustainable development,
- Nuclear chemistry and environment.

Innovative teaching methods

Active teaching methods are offered to students through a Fab Lab, virtual reality and creativity rooms, and entrepreneurship projects at the cross-section between innovation and different disciplines: EPIICs project («Entreprendre, Projet d'Innovation et Intelligence Collective»). In parallel, ENSCM has been recognised as an Apple Distinguished School for 2021-2024 period. By introducing the iPad for all aspects of the curriculum, teachers and students are using and applying technology to transform a student's educational experience, enabling them to take control of their own learning.

In-company trainings & international experiences

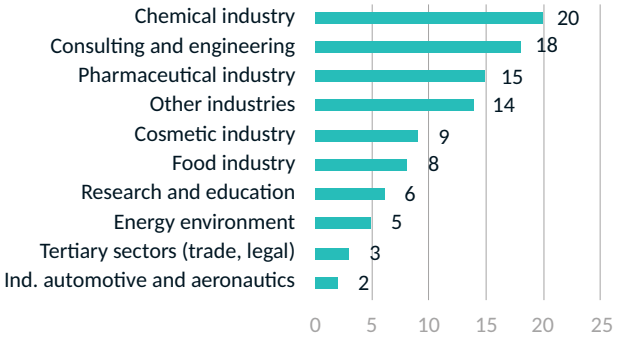
ENSCM students have a minimum of 48-week internships over the 3 years in diversified companies, thanks to strong connections with large industrial groups and SMEs – SMIs in France and abroad. 100% of our students complete at least one long stay in a company. Aware of the globalisation of economy and the competitive evolution of chemical industry, an international outlook through the practice of two foreign languages and a mandatory experience abroad (in a company or university) is systematically proposed to our students.

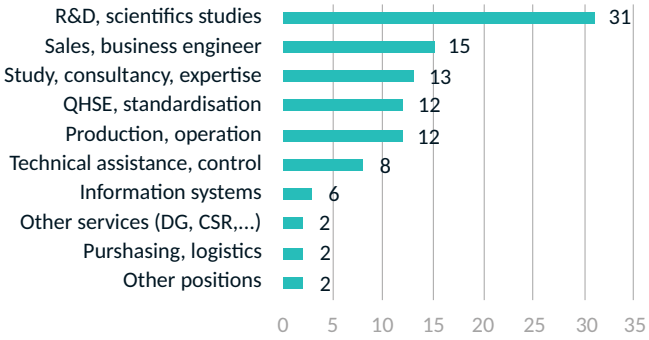
Links between research & innovation

During their curriculum, researchers from the Chemistry Research Department welcome ENSCM students from the 3rd to the 5th academic year. These direct interactions with professors and researchers allow students to have access to all our laboratories through projects, courses and research internships required to complete their studies.

Jobs & careers

The multidisciplinary curriculum allows ENSCM-graduate engineers to carry out a wide array of careers, from research to production and to combine managerial responsibilities in various industries including chemistry, health or materials in all their fields of applications, including energy, environment and sustainable development sectors.





Percentage distribution of graduate profiles hired by profession.

Doctoral school Balard Chemical Sciences

Number of students: 275 PhD students, 53% women
Appeal: 41% of doctoral students are foreign, from more than 15 nationalities
Doctoral school number: ED 459 – ED SCB
Disciplines: Analytical chemistry, materials chemistry, organic chemistry, physical chemistry

All doctorates are prepared exclusively in a doctoral school (ED), within a laboratory or a research team recognised following a national evaluation and under the responsibility of a thesis director attached to this ED. The ED SCB is essentially a training through research, to research and innovation in line with the policy of structuring chemistry on the Montpellier site with the creation of the Chemistry Research Department of the University of Montpellier.

This doctoral training constitutes a professional experience, which, after submission of the thesis, leads to the award of the degree of Doctor of the University. It also aims to maintain the existing strong links between Chemistry and its natural interfaces, i.e. Physics on the one hand (materials), and Biology on the other hand (biomolecules). It aims to train high-level researchers in all areas of chemistry: life chemistry, materials chemistry, modelling, membranes, environment and marine chemistry, drug chemistry, nuclear fuel cycle...

PhD diploma & its specialisations

1. **Biomolecular chemistry and engineering**
2. **Chemistry and physico-chemistry of materials**
3. **Separation chemistry, materials and processes**
4. **Theoretical chemistry and modelling**

The research is based on 3 thematic areas around, energy, materials and vectors, valorisation of natural resources and sustainable chemistry processes, health and human protection (from living molecules to materials, new methodologies, new processes).

In addition to this research-based training, doctoral students follow training courses related to their research project as well as those useful to their professional project. Scientific training is offered (cycles of conferences, seminars, symposiums, teaching units of the UM, ENSCM and IMT Mines d'Alès masters, workshops and thematic schools...). These are complemented by training courses designed to develop general culture, mastery of English (methodological courses, seminars, conferences and writing the thesis in English) and to prepare them for professional integration. These are gathered and provided by the Doctoral College of the University of Montpellier.

The doctoral school encourages the international mobility of its doctoral students within the framework of international conferences to present an oral communication and within the framework of collaborations with foreign countries to carry out manipulations or learn a technique. Among some of its specific actions, the ED encourages its doctoral students to promote and popularise research as long as their interventions are subject to prior pedagogical training.

The ENSCM, the ED SCB and the Doctoral College of the University of Montpellier have joined forces to offer a «Competences for Business» (CPE) course. The objective of this course is to boost the employability of PhDs in companies by providing doctoral students with the skills expected by companies and by offering them an opening into the socio-economic world.

The ED SCB offers doctoral students specific training in separation chemistry in the form of a SPOC managed by the Institut National des Sciences et Techniques Nucléaires (INSTN) as well as training in NMR managed by the ENSCM.

Educational innovation

Thanks to the support of I-SITE MUSE via its TAKE-OFF funding, the Labex CheMISyst and the French Ministry of Higher Education and Research, teaching chemistry classes is at the core of a wide-ranging programme for educational transformation, which is centred on new teaching formats, but also on the acquisition of scientific and managerial skills.

The teachers from the Chemistry Research Department are involved in the Faculty of Sciences, Pharmacy, the IUT and in the ENSCM, INSTM and Polytech' engineering schools. They are responsible for many serious games of all types of serious games, escape games, board games, smartphone applications, virtual reality equipment, online or open trainings.

This section deals with the latest creations in educational innovations used from the first year of the degree course.

Several works and scientific articles on educational innovation have also been written by chemistry teachers at the University of Montpellier. These publications from Montpellier mean that France has increased international exposure, and represent 25% of French production in the Journal of Chemical Education (American Chemical Society).

Escape games. «Chem'Sc@pe» and «Exit» projects, awarded of the call for MUSE projects, have been developed on the topics of organic chemistry and laboratory security for students from the Faculty of Science and the ENSCM. Chem'sc@pe can also be used for other scientific disciplines.

Virtual reality. Equipped with a virtual reality room where its chemistry training is held, Montpellier is one of the leading French sites and features among the leading sites globally. The teaching delivered to chemistry students from master, engineering students to PhD offers complementary vision to molecular modelling and drug design courses. Funded by I-SITE MUSE.

Hybrid games. «Reactions», «Stereochemistry», «Organic reactions», «Crystallography the game XTG 349» are the games available on smartphone applications, or as board or card games. They are available in four languages and cover basic topics of organic and general chemistry.

Card games and role-playing games.
Aimed at DUT students, «Hacking» is an Arduino card game for the development of technical skills and transferable skills necessary for the characterisation of materials. «Hack and jaM» is when a role-playing game allows the DUT students to develop skills in project management, team working and transferable skills essential for the industrial sector.

Board game: Science of materials and sustainable development. «Grow My Planet» introduces the life cycle of metals; from mineral extraction (limited resource), smelting (transforming the ore into a metal), manufacturing (the art of transforming the material into an object) and usage (mainstream applications).

Practical work in chemical magic and environmentally friendly methods.
During the practical works carried out at undergraduate degree and Master's degree level, environmentally friendly methods using microwave and mechanochemistry are taught and the synthesis of materials with outstanding properties such as synthesis of precious stones, ferrofluids, superconductors are developed.

SPOC - Online training for chemical recycling.
The recycling of metals, such as those contained in electronic waste requires certain processes to be mastered in order to obtain high-performance recycled materials that have a new economic value. This private online training (SPOC) offers the opportunity to study the scientific basis of recycling. Entitled «Recycling Chemistry: From theory to practice» this SPOC can be followed by researchers, post-doctoral and doctoral students.

UNISCIEL - University of Science Online.
Created by the French Ministry of Higher Education and Research, UNISCIEL brings together more than 50 universities and engineering schools organized in thematic digital universities (UNT). In Montpellier, several teachers are involved in developing high-quality digital resources in chemistry (courses, evaluations) accessible to all French-speaking students around the world to promote success in chemical education.

Summary

5 CONTRIBUTIONS & SIGNIFICANT EVENTS

Research addressing societal challenges

The players from the Chemistry Research Department carry out their research in the context of leading national, international and partnership collaborations. The four institutes are distinguished by numerous significant events associated with quality indicators and show diversity in their fields of activity.

This section identifies the latest academic discoveries, technological developments and research findings. These significant events are presented in the form of research strategies/results with clearly visible benefits, whether that be in terms of major projects (ANR, industrial, European, maturation...), high impact publications, patents and licences or instrumental development.

Health

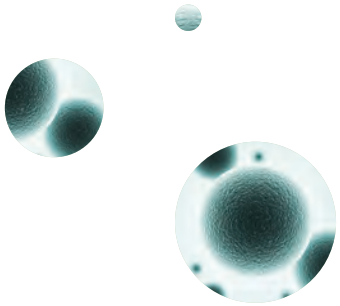
Role of epitranscriptomics in cancer to understand the intimate mechanisms involved in the translation of mRNA into proteins. The synthesis of capped RNA and methylated capped RNA involved in RNA translation, which has been developed by an IBMM team in partnership with Cornell University, has led to an important step forward in epitranscriptomics in the fight against cancer (published in Nature 2017, Nature Chemical Biology 2019, Molecular Cell 2019).

An NMR study on the conformation of a family of membrane receptors GPCRs. The Ghrelin receptor, a major receptor in the control of food intake have been studied in partnership with Brian Kobilka from Stanford University (USA), winner of the 2012 Nobel Prize in Chemistry (the project was financed by a European contract).

Fighting against neurodegenerative diseases. The development of a neuron/muscle cell co-culture demonstrator on multi-electrode arrays in a microfluidic chamber was carried out as part of the NMJ-on-chip project, for the microfluidic modelling of human neurodegenerative diseases and the impact of RNA transport in the neuromuscular junction. The project was funded by I-SITE MUSE, in partnership with IES, IGMM, PhyMedExp-Inserm, L2C, and Tel Aviv University.

Development of an innovative RNA synthetic process. As a result of IBMM's work, this unique patented process has been licensed to and marketed by the company, ChemGenes corp (USA).

Analysis of the movement of nanoparticles. IBMM has patented and developed a prototype designed for the analysis of Taylor dispersion, facilitating the measurements of the diffusion coefficient under perfectly controlled conditions. This is in coupling with sensors adapted to the analysis of nanoparticles and biopolymers. The prototype uses unique experimental data processing software in order to gather information on the size distribution of the analysed samples.



Methodologies

Synchroton radiation for the study of separation processes. Within the framework of a partnership between the three units (ICSM, SOLEIL and ISEC Marcoule), a device was created to carry out measurements coupling SAXS/WAXS and EXAFS techniques on the MARS line at Soleil synchrotron (adjustment of a transport cell, beam size and collimation, minimisation of parasitic scattering, experimental resolution, optimal energy range...). These pioneering SAXS/WAXS measurements in Europe taken of a transuranic material have permitted us to gain access to speciation at both molecular and supramolecular levels (complexation and aggregation) within organic phases, involved in uranium or lanthanide separation processes, and thereby to establish the structural link between the atomic and nanometric scales of these organic liquid to liquid extraction phases.

Modelling liquid/liquid extraction. An original calculation strategy based on a colloidal and self-assemblies approach was developed to predict the solvent extraction of rare earth. Such modelling allowed for complexation and molecular dynamics to be set at fairly small scales (a few nanometers and nanoseconds) in perfect alignment with experimental measurements.

Method for 3D monitoring of materials at a microscopic scale. The dissolution and/or corrosion processes of materials are generally driven by local defects, such as pores or grain boundaries. The study carried out on the evolution of a surface during dissolution allows us to observe, directly, the effect at microscopic scale. Based on the possibility of reconstructing 3D images of a surface from a series of SEM images, a strategy to study the evolution of a surface has been developed and validated. This tool paves the way for new and promising perspectives on the study of dissolution of ceramic materials but also, more widely, for all studies that require in-depth knowledge of surfaces.

Environment

IBMM Institut des Biomolécules Max Mousseron

A prototype to protect bees. A prototype equipped with a beehive has been developed within the framework of the MUSE (SuperBeeLive project) and has been co-funded by LabEx NUMEV (Digital, Material and Modelling Solutions for the Environment and Life Sciences). It provides a platform for the study of bees, beehives and honey. This unprecedented tool, combining cameras and electronic sensors, facilitates real-time monitoring of the bee colony's super-organism and of its environment. The main purpose of this project is to describe the sequence of events that give rise to the destabilisation and death of a bee colony after it has suffered chronic exposure to neurotoxic insecticides. This experimental beehive is situated at the CEFE (Centre of Functional and Evolutionary Ecology) experimental site in Montpellier.

iem Institut Européen des Membranes

Design of a wide range of membranes by Atomic Layer Deposition. Atomic Layer Deposition (ALD) is a scalable deposition technique used to deposit high quality materials with high uniformity, controlled growth that are highly compliant. ALD offers unprecedented versatility and capabilities compared to conventional deposition methods. ALD opens up new possibilities for the design of a wide range of membranes with functional nanolayers. Since 2012, the IEM has developed 7 ALD facilities, placing the IEM as the reference laboratory at world level for the use of ALD in the field of membranes.

ICSM

Decontamination of mine effluents on mining sites. To anticipate standards becoming stricter for the release of uranium into the environment, a method used to immobilise the uranyl contained in mining water by precipitating a particularly stable uranium-bearing phase, meta-torbernite, was suggested. The origins of this solution lies in the choice of a matrix (copper-based hydroxyapatite), serving both as a support for the precipitation and as a source of phosphorus and copper necessary for the formation of meta-torbernite. The synthesis for the support matrix were optimised, particularly for efficiency in the water treatment, leading to a rapid and significant reduction in the concentration of uranium and radium in the solution, Orano filed a patent in 2016.

Towards a reduction of industrial effluents. Surfactant-free micro emulsions in the restricted field of hydrometallurgy was explored with the University of Regensburg (Germany). This has allowed to understand the mechanism of action for solubilising agents that are not detergents - the class of hydrotropes. Combination of advances, extraction processes (with less solvent, less extractant but nonetheless more efficient) new unconventional solvents and systems were explored.

Extraction of uranium from seawater. A new resin synthesis process of copolymerization of bis-catecholamide allows us to obtain cross-linked resins that are extremely effective in extracting uranium from seawater. Certain polymers have surprising capacities, some reaching 450 mg/g and unrivalled selectivity with respect to competing metals, in comparison with the performances of resins developed in Japan and the United States. Funded by the CNRS, project should be followed by pilot tests and a technical and economic feasibility studies.

ICGM Institut Charles Gerhardt Montpellier

Environmental impact & aerospace industry. The use of renewable resources and the replacement of highly toxic molecules by plant-based building blocks has facilitated the synthesis of new resole-type polymer networks for the development of ablative thermal protection composites to be used in propellant nozzles for the Ariane Group. The ICGM has also started work to implement biosourced polymers in aqueous media in the form of synthetic biosourced latexes.

Scientific advances in flexible MOF materials for gas treatment. In the field of flexible MOF porous hybrid materials, the computational development of force fields has allowed to describe the respiration processes of porous solids under various stimuli. The implementation of an original approach, coupling pressure X-ray diffraction and molecular simulation has allowed the potential of these flexible materials for mechanical energy storage to be explored. Moreover, a new concept for CO_2 capture, based on the use of breathable MOF materials, whose open porosity is controlled by the application of an electric field or mechanical pressure to allow the selective absorption of CO_2, in relation to other molecules, such as methane and dinitrogen, has been predicted, and then experimentally confirmed.

Water

Institut Européen des Membranes

Artificial water channels in biomimetic membranes for the desalination of seawater. Artificial water channels have recently been suggested as alternatives to aquaporins to increase the flow of water through reverse osmosis membranes. This research is focused on the design and synthesis of membranes incorporating artificial water channels of the Imidazole-quartet type that are synergistically-speaking, very high permeabilities (2-3 LMH/bar) and selectivity (NaCl rejection rate > 99%), which meet the stringent requirements of desalination processes. These extremely promising results are currently being developed with an industrial partner.

Treatment of emerging micropollutants. The aim is to treat emerging micropollutants contained in water (pharmaceuticals, endocrine disruptors, pesticides, etc.) in order to eventually allow effluents to be discharged into the environment or water to be reused, by closing the water cycle. This involves studying the coupling of membrane operations (UF/NF) with advanced oxidation processes (AOP), in particular photocatalysis and ozonation. This action has led to the development of a new concept of photocatalytic light membrane fabric and the coupling of ozonation with nanofiltration for the reuse of wastewater.

Electrochemistry and membranes for water treatment & energy. An innovative concept for the treatment of effluents loaded with biorefractory compounds was developed as well as a membrane pilot equipped with a new type of electrodes. This system operates continuously without chemical input, using a combination of forced convection and advanced oxidation processes. It allows for the destruction of all toxic compounds and by-products, both on synthetic and real effluents. In order to manufacture the cathode, new solutions have been suggested by modifying commercial 3D carbon felts with 2D structures. In order to manufacture the anode, methods have been proposed to obtain porous electronically conductive titanium oxide membranes with electrocatalytic properties adapted to the generation of hydroxyl radicals and which are therefore usable in Electrochemically Reactive Membranes (ERM).

Assembly of block copolymers: towards high-performance and intelligent membranes. This work has demonstrated that it is possible to produce isoporous ultrafiltration membranes through a unique self-assembly route for copolymers. The process developed consists of the preparation and self-assembly of building blocks of perfectly controlled shape, size and functionality. The copolymer structure and the synthesis route used have enabled a wide variety of smart, multifunctional and dynamic membranes to be created. Examples include magneto-responsive membranes, anti-bioadhesive membranes and membranes that mimic the biological process of translocation. By nanostructuring materials without defects and on a large surface area, the performance of current commercial membranes can be greatly exceeded.

ICGM
Institut Charles Gerhardt Montpellier

New processes for water treatment. The ICGM's activities in the field of ionic phases, of the «ionosilica» type in particular, constitute a subject of interest with significant progress for ICGM. Most of these materials are synthesised by the sol-gel process from ionic precursors. Initially approached from a fundamental point of view, and also within the second phase, the works were the subject of research in the field of water treatment (patent agreement).

Circular economy

Recycling of the rare earth elements. An original assembly that combines experimental, theoretical and predictive model approaches for a better understanding of the mechanisms of liquid to liquid extraction has led to the development of a new, faster, more accurate, cost-effective and environmentally friendly rare earth recycling process. This new understanding of the mechanisms involved in ion-selective transfer should be used to optimise processes for other unsolved problems, such as: heavy metals, hormones, pharmaceutical contamination in drinking water or new recycling opportunities. It will also make way for the economically viable recovery of metals from a fast-growing «urban mine», i.e. the various metals contained in «waste» generated by lithium ion batteries, supercapacitors, wind turbines, supported catalysts and used up fuel cells. The project was funded by an ERC grant for 2013-2018.

Recycling of gold from electrical and electronic waste, D3E. Within the framework of criticality for noble metals, the ICSM and SOVAMEP, an SME in the recycling sector, have joined forces in a collaborative project funded by the Occitania Region (Readynov), with a view to developing a technological solution for recycling the gold contained in industrial waste (electronics, fashion...). The existing processes in use are based on a dissolution (or leaching) stage, requiring the use of highly corrosive reagents, and therefore, harmful or even toxic with nitrogen oxides. Two innovative hydrometallurgical solutions for the recovery of gold have been developed to replace aqua regia treatment with less harmful, less dangerous and less costly reagents, while taking into account environmental, health and regulatory constraints. Several approaches and applied studies have been conducted and validated in the laboratory. Their development and implementation are now planned on a pre-industrial scale for 2021.

ICGM
Institut Charles Gerhardt Montpellier

Circular economy & recycling of precious metals. The aspects linked to the use of processes in unconventional settings were also explored by several groups. For instance, 2017 marked the awarding of an ERC Consolidator Grant on the topic of «Mechanochemistry: a unique opportunity for oxygen isotope labelling and NMR spectroscopy». The ICGM has also coordinated a European project from 2018 to 2021 on the recycling of precious metals by polymer-assisted supercritical CO_2 extraction.

iem Institut Européen des Membranes

Membrane & biological process for water reuse: from WWTP to STARR (STAtion for the Recovery of Resources from Wastewater: water, energy, nutrient). This topic is derived from the UN Sustainable Development Goals and the principles of circular economy, in particular, the two axes related to waste water treatment (1) securing the production of secondary raw material (reuse of water and recovery of nutrients) and (2) reducing energy consumption. In particular, it has led to numerous partnerships that have enabled the development of demonstrators at the end of waste water treatment plants and field trials. This work made it possible to defend an Innovation Deal (Sustainable waste water treatment combining anaerobic membrane technology and water reuse) at the European level and, in particular, led to the creation of an IWA Task Group (Membrane Bioreactors Modelling and Control).

Energy

Energy challenges & awards. Several advances in the field of electrochemistry have been awarded with various distinctions. For instance, the integrated approach in the nanostructuring of membrane assembly components for fuel cell electrodes was funded by an ERC Starting Grant (2018). The SCF Energy Division Research Award 2017 awarded the advances in the synthesis of non-noble catalysts for PEMFC and in the understanding of their operando degradation mechanisms facilitating their stabilisation. This award emphasised the synthesis of custom-made ionic liquids, thereby opening up a new field on multifunctional electrolytes. The visibility of activities in the fields of energy conversion and storage and the influence of the staff involved in this research have been recognised in the awarding of 15 European contracts since 2014. Fruitful partnerships have also led to advances in the field of fluorinated polymer electrolytes.

Development of innovative conceptual & theoretical approaches. Several significant advances have been made in the field of electro-chemical energy storage to predict the electro-chemical potential of battery electrode materials, to design in silico new high energy density materials and to access the quantum processing of the complex interfaces of these devices in a grand canonical approach pioneered in the field.

Scientific advances in flexible MOF materials for gas treatment. In order to meet the requirements of gas separation under aggressive industrial conditions (temperature, pressure, abrasion, cycling, poisons...), an original strategy has been developed to contain a continuous network of MOF materials (Metal Organic Framework: molecular sieve membrane) inside the macropores of an industrial ceramic support. This approach produces a series of high-performance and robust membranes capable of meeting, in particular, the requirements of separating dilute rare gases from the effluents of nuclear power plants in the event of an incident within the framework of a large-scale project. Industrial development is currently under consideration for these membranes.

Engineering of nanosheets for the preparation of new separation membranes & electrocatalysis. This research aims to develop new methods for the preparation of exfoliated nanosheets (graphene, graphene oxide, metal chalcogenide) and to optimise their physico-chemical properties, in particular by controlling the density of defects, their crystal structure or their surface. Therefore, the influence of the surface chemistry of nanosheets on the separation performance of nano-laminated membranes has been studied. At the same time, the electro-catalytic properties of 2D nanosheets are also being investigated, with the aim of developing new electrolysis or photoelectrolysis cells for H_2 production and electro-chemical CO_2 reduction.

Materials

New material for nuclear control. The synthesis of actinide oxide microspheres was carried out by the hydrothermal conversion of uranium aspartate (IV). Optimal conditions were established in order to create mono-dispersed particles. These microspheres have successfully been used to conduct in-situ studies of UO_2 sintering by HT-ESEM. They are also being studied in partnership with CEA/DAM and the International Atomic Energy Agency (IAEA) as reference materials for international nuclear safeguarding operations.

Towards a new method of manufacturing glass-ceramics, thanks to utilising the sensitivity of neutron thermodiffraction, and then stabilisation to our advantage to produce glass-ceramics by pressing metastable phases with optimised properties.

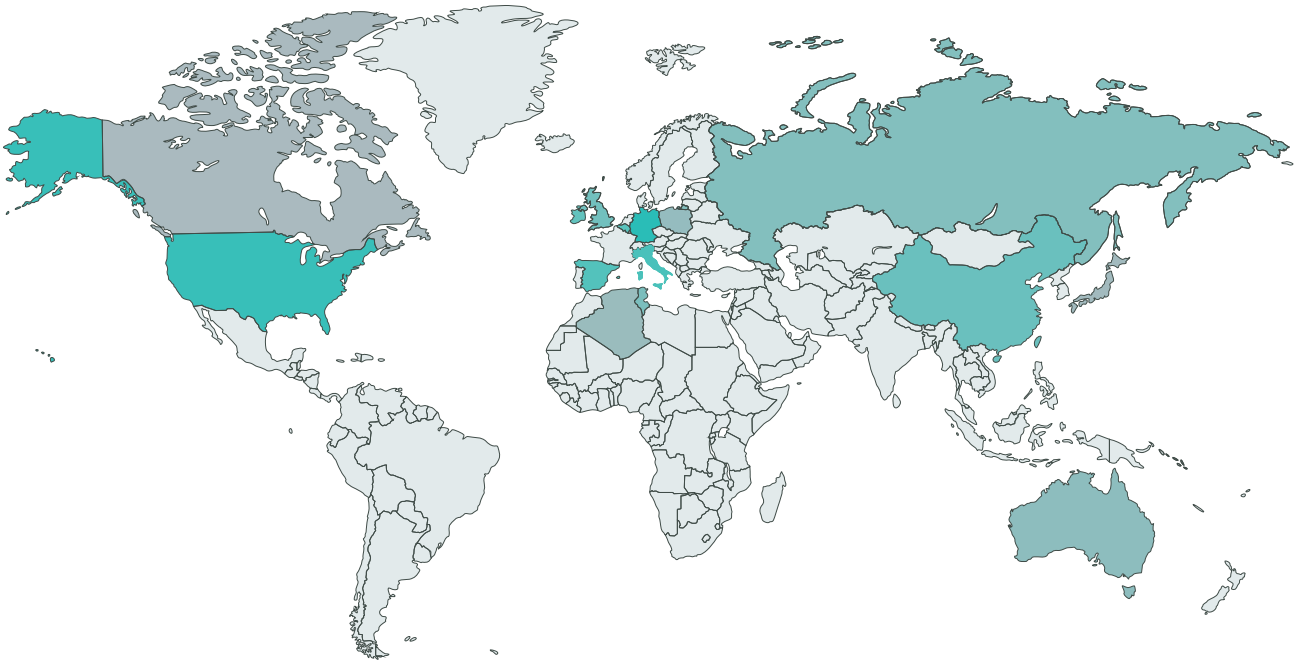
Scientific and technological advances in R&D. In situ monitoring of the reactivity of solids by X-ray diffraction on a single crystal represents a real breakthrough in the field. The development of specific reaction cells for electro-chemically controlled oxygen intercalation or that could be used to operate at different temperatures and oxygen partial pressures were required for this work.

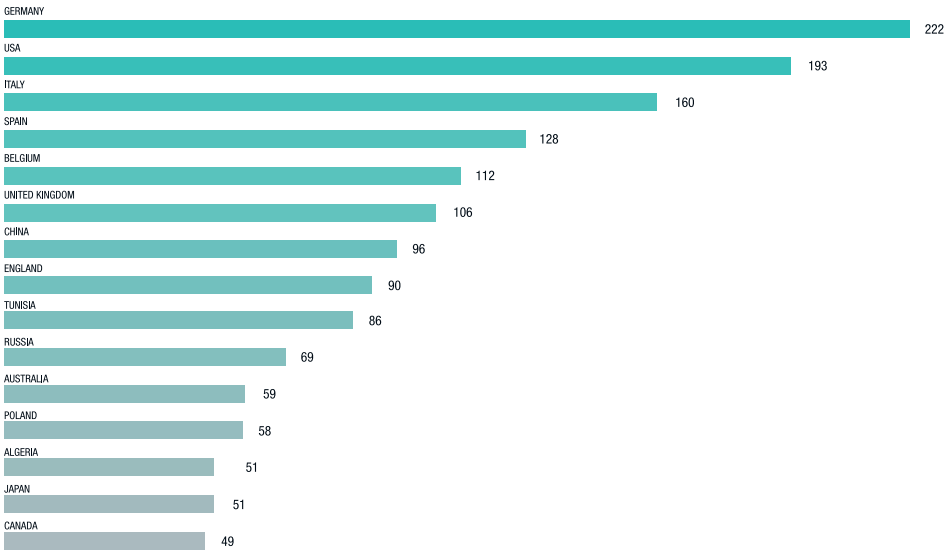
Major partnerships

INTERNATIONAL COLLABORATIONS & PUBLICATIONS

60% of the Chemistry Research Department's scientific articles are published with at least one foreign partner.

50% of the all co-publications are signed with the TOP international scientific publishers from North America, Europe, Africa to Asia.



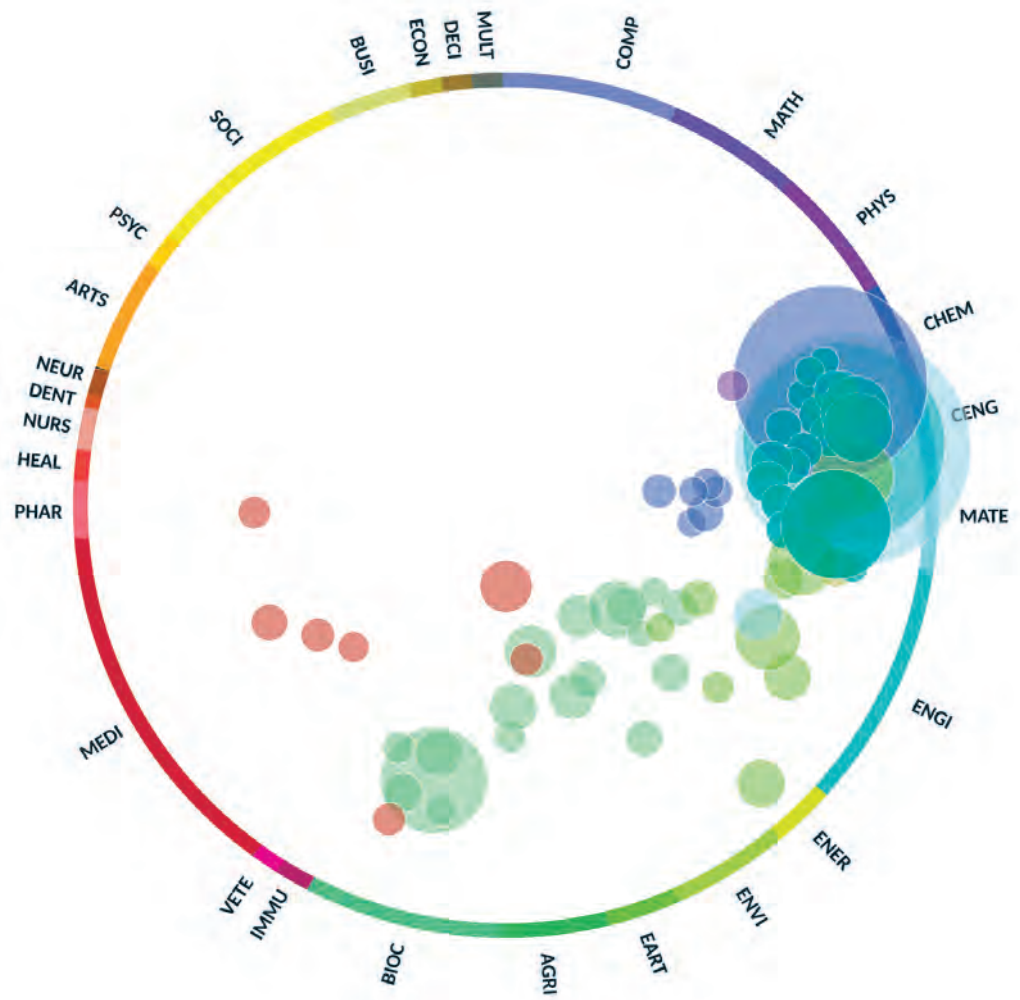


List of the 15 first country partners.*

*Bibliometric studies from Chantal Salson - Based on publications between 2015-2020. Source web of science updated April 28th 2020.

Major partnerships

SCIENTIFIC PROFILE OF THE CHEMISTRY RESEARCH DEPARTMENT'S PUBLICATIONS BY THEME



Topic Clusters

COMP	Computer Science	MEDI	Medecine
MATH	Mathematics	PHAR	Pharmacology, Toxicology and Pharmaceutics
PHYS	Physics and Astronomy	HEAL	Health Professions
CHEM	Chemistry	NURS	Nursing
CENG	Chemical Engineering	DENT	Dentistry
MATE	Materials Science	NEUR	Neuroscience
ENGI	Engineering	ARTS	Arts and Humanities
ENER	Energy	PSYC	Psychology
ENVI	Environmental Science	SOCI	Social Sciences
EART	Earth and Planetary Science	BUSI	Business, Management and Accounting
AGRI	Agricultural and Biological Sciences	ECON	Economics, Econometrics and Finance
BIOC	Biochemistry, Genetics and Molecular Biology	DECI	Decision Sciences
IMMU	Immunology and Microbiology	MULT	Multidisciplinary
VETE	Veterinary		

*updated up to November 24th 2020 - Scopus Source

Major partnerships

SCIENTIFIC IMPACT OF THE CHEMISTRY RESEARCH DEPARTMENT'S PUBLICATIONS BY JOURNAL QUARTILE

77% **of the Chemistry Department's scientific articles are published in Q1.***

93% **of publications are listed in Q1 to Q2.***

Share of publications per Journal quartile by CiteScore Percentile

Publication

Quartiles	Publication shares (%)
Q1 (top 25%)	77.2
Q2 (top 26% - 50%)	15.8
Q3 (top 51% - 75%)	5.1
Q4 (top 76% - 100%)	1.9

Cumulatives shares	Publication shares (%)
Q1 to Q2 (top 50%)	93.0

*Data analysed - Source: Scopus, publications between 2015-2020 up to 24 Nov 2020

Major partnerships

IBMM Institut des Biomolécules Max Mousseron

In its ecosystem

IBMM's research has a strong focus on human health and benefits from a very rich and particularly attractive local scientific environment. The transferable nature of chemistry allows it to be perfectly integrated into this local ecosystem. The institute has several partnerships that allow it to respond to calls for projects for local devices (MUSE, SIRIC, Région LR...) with almost all of the biology institutes on the Montpellier site (IGF, IGH, ICGM, IRIM, IRCM...), as well as projects related to clinicians (FHU Regenhab, IT4Care, IRC). 30 projects carried out in partnership with on-site laboratories have been funded by the MUSE consortium since 2017. 14 projects have been funded by the Occitanie Region since 2014, and a further 2 projects have been funded by the Site de Recherche Intégrée sur le Cancer (Integrated Cancer Research Site - SIRIC) since 2018.

Since 2014, 31 collaborative projects gave rise to maturation operations with SATT AxLR, some of which have led to the creation of start-ups. This local and multidisciplinary network is a major lever to feed Montpellier's ecosystem.

Dedicated to the synthesis of biomolecules, the Synbio3 platform devotes 60% of its activity to Montpellier's biology teams. This activity contributes to the consolidation of a strong network between chemists, biologists and clinicians. It will allow new interdisciplinary and translational research projects to be developed.

At local level

Examples of partnerships based on complementary expertise between the members of the Chemistry Research Department for Human Health.

ICGM and IBMM's combined expertise have resulted in the discovery of a family of original hybrid materials based on biomolecules. The assembly of these biologically active materials is fixed by inorganic polymerization. The materials themselves have been the subject of nearly 40 publications and have fuelled several partnerships with biologists and clinicians in Montpellier. There are several applications, and they cover the design of nanovectors for cancer treatment, imaging, regenerative medicine and tissue engineering, intelligent medical devices for the treatment of wounds, and systems to detect circulating biomarkers. 8 funded research projects use this technology, 4 patents have arisen from this work and two industrial contracts have been established.

The development of targeted laser-activated nanovectors to be used for anti-cancer therapy is the result of a partnership between ICGM and IBMM that, over the last ten years, has led to more than 40 scientific articles, numerous national and international contracts and 4 patents. Based on the work carried out on targeting and its application to lysosomal diseases, the NanoMedSyn spin-off was created in 2012. Today, this company employs 5 researchers on permanent contracts and develops different applications for their patented and licensed targeting molecules.

At national level

IBMM participates in several national research groups (GDR). For example, some GDRs can be cited, such as GDR 3545 «G-Protein-coupled Receptors: from physiology to drugs (GPCR-Physio-Med)», the GDR Physiological Med, GDR 3749 Prometheus of hydrometallurgy, GDR 2088 BIOMIM (Biomimicry and Bioinspiration), GDR 2095 ChemBio, GDR 2083 RNA, GDR Repairing the Human, GDR 2002 or-nano, GDR Happybio, GDR 2037 AIM Molecular imaging agents, GDR 2082 APPICOM is named «Integrative approach for a multi-scale understanding of the function of membrane proteins».

IBMM is also involved in France Life Imaging's (FLI) Management Committee, the «Biology and Health Infrastructure», managed by the CEA and coordinated by Vincent Lebon. The Director of IBMM is in charge of the «molecular imaging agents» work package, the objective of which is to facilitate partnerships between all academic and industrial partners.

Major partnerships

At national level

The ICSM, by taking advantage of its exceptional scientific and academic environment with the proximity of the Marcoule laboratories, the University of Montpellier, the ENSCM, and at the national level with numerous laboratories specialising in materials science, modelling and more widely in separation and analytical chemistry processes (IPNO, CEMTHI, IJL, PNO-Orsay, UPMC-PHENIX, UMR St Gobain (Paris, Cavaillon), Collège de France, UJF Grenoble...), has long established fruitful scientific partnerships and built an extensive network of partnerships. More than 90 scientific or contractual partnerships (combining all activities), whether academic, industrial or with CEA departments, have been identified in national projects (ANR, PIA, labEx CheMISyst). The Institute responds to calls for projects each year from the ANR, the Scientists' and Young Researchers' programmes and programmes dedicated to different topics and adapted to its research. One or two ANR projects are funded in this way each year. Taking into consideration the size of the Institute, this newfound success with the ANR is quite remarkable. Through the ANR, the ICSM works with a dozen manufacturers: Orano, VEOLIA, TND, Extracthive, CTI, Woellner, Oleos, Cordouan and DSM. Furthermore, 3 PIA ANDRA projects have been funded, 1 of which is under way. By taking advantage of the reinforced links between disciplines via the CheMISyst Laboratory of Excellence, the ICSM has been very dynamic in this LabEx, both through its positioning at the level of coordination but also through its involvement in 13 research projects, 7 as a leader and 6 as a partner.

At european level

The unit has developed a network of partnerships with the universities of Barcelona (ANR), Lubjiana, Huelva (hubAndalucia), Copenhagen, Amsterdam (ANR), Jülich (CD SCB), Delf, Messina, the Imperial college of London, as well as with the Max-Planck of Berlin and Potsdam (LEA-SONO, LIA NISI), and the KIT of Karlsruhe. Our teams recently met with the GmbH in Jülich and partnerships were built in the field of materials chemistry. Furthermore, the Institute has been involved in European networks, ACSEPT and I3-ACTINET since the beginning. Up until 2017, the ICSM lent its expertise to the SACSESS (Safety of Actinide Separation Processes), TALISMAN (Trans-national Access to Large Infrastructures for a Safe MAnagement of actiNides), ASGARD (Advanced fuelS for Generation IV reActors: Reprocessing and Dissolution), Euract-NMR (Trans-national Access to Unique European Actinide and Radiological NMR Facilities), and GENTLE (Graduate and Executive Nuclear Training and Lifelong Education). It currently takes part in the following European programmes: GENIORS, INWARD, IAEA and EURAD. Moreover, the ICSM led the ERC «REE-Cycle» Marcoule-Grenoble DRF/DRT between 2012 and 2018, in partnership with the CEA (DES/Marcoule and DRT/Grenoble).

At international level

The institute has developed a network of partnerships with the universities of Bangalore, Beirut (CEDRE), Canberra, Melbourne, Johannesburg, Michigan, Northwestern, Florida State University, MIT-Cambridge, Kyoto, Notre Dame, ICPE Moscow, UFS, Tizi Ouzou, Monastir, as well as more recently with the CSIR-NML laboratories of Jamshedpur (CEFIPRA) and the Nanyang University of Technology (SCARCE).

These partnerships are at the heart of the ICSM's international appeal, which can be measured by the desire of trainees, doctoral students and post-doctoral students to join the unit to complete their training. Therefore, 30 nationalities are represented at the Institute, including 17 from outside of Europe (China, Vietnam, Mali, Congo, Senegal, Russia, Colombia, Guatemala, Argentina, Tunisia, Algeria, Lebanon, India, Ukraine, Mongolia, Peru and South Africa).

Furthermore, 25 French or foreign researchers and professors were invited for various periods (ranging from one day to one month) to present their research work and share their experience with ICSM researchers. For the most part, these invitations have been the starting point for the establishment of several scientific and contractual partnerships.

The Institute takes part in many National Research Groups (NRGs) with the «Nuclear, Energy, Environment, Waste, Society» (NEEDS) programme, the GDR «charged membrane systems», the GDR «Prometheus», the GDR «SciNEE» (Nuclear Sciences for Energy and the Environment), and the GDR CAVITATION led by the ICSM.

Major partnerships

ICGM
Institut Charles Gerhardt Montpellier

At local level

ICGM's research is dedicated to the elaboration, the synthesis and the characterization of functional materials with emphasis on applications in health, energy and environment. As such the Institute is fully integrated in the local research landscape with strong and numerous collaborations with the other Institutes in chemistry (IBMM, IEM and ICSM) but also with other Institutes in Biology (FHU REGENHAB), Physics (L2C, IES) or Ecology (IATE, SupAgro). For example, the project OPTIVIT (leader Caroline Vigreux, ICGM) has been financed by the MUSE initiative and is a collaborative program between L2C, IES, ITAP and ICGM to develop glass materials for sensors used in the detection of pollutants for the wine industry.

At national level

ICGM is particularly well positioned at the National level with a network of diverse and fruitful collaborations with many different research institutes as illustrated by the amount of ANR funded in the last three years (ca. 40). These collaborative projects are conducted either with other academic groups (PRC) or with companies (PRCE) and a significant number of them are coordinated by ICGM members. In addition, the projects cover a wide spectrum of topics as illustrated by the diversity of the ANR Panel that have granted the funding.

The participation in various GRD is also one aspect of the impact of research done in ICGM at the national level: GDR SOPHY (Soft Physics for Hard Materials), GRD Polymers and Oceans, GDR NINO (Inorganic Nanostructures from Solution Chemistry), GDR CHALCO (Chalcogenide Materials), GDR SOLVATE (Solvatation : Theoretical and Experimental Approaches), GDR THEMS.

At european & international levels

In 2018, the creation of a joint laboratory with the University of Gumma (Japan) allowed us to reinforce existing links with this institution. This partnership has led to the recruitment of an assistant professor, (Dr. Yujia Liu) and in researchers spending time at both sites. The research projects are targeted at the design and synthesis of original organic and inorganic hybrid materials.

The ICGM is involved in more than 15 different projects funded by the RC along different schemes. As an example, Evelina Colacino, associate Professor from University of Montpellier at the ICGM, will lead and coordinate a 7.4-million-euro project funded by the European Commission's Horizon Europe Research and Innovation Programme. This funding will bring the IMPACTIVE project to life. IMPACTIVE aims at lowering the carbon footprint and environmental impact of several chemical processes, inducing chemical reactions by mechanical forces (e.g. compression, tension, shear force, impact), in the absence of solvents, while reducing the use of energy and the production of CO_2. This increases autonomy, as the supply chain becomes faster and more resilient, resulting in lower prices and more competition. Mechanochemical techniques allow savings not only in terms of how the synthesis is conceived, but also in terms of waste management (solid and potentially less harmful waste being much easier to dispose of than solvents). The consortium involved in the EU IMPACTIVE project will build a proof of concept to raise awareness of the potential of this new technology for the preparation of active pharmaceutical ingredients.

Major partnerships

Institut Européen des Membranes

At local level

The IEM is fully integrated and active in the local ecosystem. It relies on various tools, such as the LabEx CheMISyst/LabUM chemistry, the Carnot Institute Chemistry Balard Cirimat, 3 technical platforms and 2 international chairs. The unit's researchers and teacher/researchers are attached to the «Sciences Chimiques Balard - ED 459» doctoral school for the DM3 and IP2 departments and to the «GAIA - ED 584» doctoral school «GAIA» for the GPM department.

The IEM is increasingly involved with the Metropolis of Montpellier in its development projects. We can cite the European project Recycled Water for LIFE (Limit freshwater withdrawals by developing multi-purpose recycled) concerning the mobilisation of treated water from waste water treatment plants (REUT) for urban uses (watering, fire defence, cleaning...) and the governance of this raw water, and for which the IEM is one of the partners.

At national level

Over the last five years, the research institute has participated in 47 ANR projects, 29 of which were as project leader. This record is significant, particularly with regard to the number of projects as a leader, and highlights the visibility of the IEM in the French landscape as well as the relevance of the research undertaken. One of its strong characteristics is its ability to establish direct contractual relations with French manufacturers, whether they are large groups, SMEs, VSEs or start-ups.

The IEM also participates in several National Research Groups (GDR) such as the H_2 Research Federation, the GDR Biomim (Bioinspiration and Biomimicry), the GDR OXYFUN (Functional Oxides: from material to device), the GDR Or-nano, the GDR SolarFuels (Solar Fuels) and the GDRI «Controlled Multifunctional Nanomaterials: from the dispersion of the nano-object to the multifunctional properties».

At international level

Over the last five years, the unit has strengthened its position at international level through its significant involvement in European programmes. In particular, the unit has participated in 15 European projects, including three «Marie Slodowska Curie-type» projects concerning student exchanges. The IEM has also coordinated a French-Russian International Associated Laboratory «LIA MEIPA» involving 2 Russian laboratories and 2 «Erasmus Mundus» Master's programmes (Erasmus Mundus Master's in Membrane Engineering (EM3E) and Erasmus Mundus Master's in Membrane Engineering for a Sustainable World (EM3E-4SW). The IEM's participation in the INNOMEM European project (Open INNOvation Test Bed for nano-enabled MEMbranes) is a strong marker of our visibility. This project brings together 32 companies and research laboratories from 10 countries and its overall objective is to prepare and support the industry of tomorrow in the field of membranes. We must also add to this the European ERC starting grant project «2D-4-CO_2» (Designing 2D Nanosheets For CO_2 Reduction and Integration into vdW Heterostructures for Artificial Photosynthesis), a prestigious contract carried out by a young researcher from the IEM.

Demonstrating the leading role of the Montpellier teams in the field of inorganic membranes in particular, the first international congress was organised at the Corum in Montpellier in 1989: the ICIM series «International Conference on Inorganic Membranes». This conference is now in its 16th year, and has been scheduled to be held in Taipei (Taiwan) in 2022. The IEM has also been the main organiser in Montpellier for several international conferences highlighting its dynamism: Materials 2014, Shaping VI 2016, Workshop RAFALD 2017, Euroboron 8, 2019.

At the same time, the IEM has always been involved in structuring operations in research and training, at several levels. These include, among others the coordination of the NanoMemPro network of excellence (2004-2008), bringing together 13 European scientific partners in the field of membrane technologies and nanotechnologies, which led to the creation of the «European Membrane House».

As far as doctoral students are concerned, we welcome more than 60% of foreign students, which is a sign of the visibility of our work and the unit's appeal. The main geographical areas are Asia, Central America and Africa, which also reflects the interest of the countries concerned in membrane science and technologies. Lastly, a large number of foreign students, mainly doctoral students, spend significant periods of time (6 months to 3 years) at the unit to complete their scientific training.

Societal actions

CONNECTING SCIENCE & SOCIETY

Whereas in the 20th century scientific knowledge essentially served the common good, science must now fulfil an additional function, that of informing the decision-makers who manage public policies. Therefore, in order to avoid public mistrust and to give confidence in the ability of science to meet the needs of society and the challenges of the future while respecting man and his environment, it must promote dialogue with society and encourage the sharing of a common scientific culture in order to enable citizens to understand and participate in the issues of the contemporary world.

Children experimenting Virtual reality on modeling protein, Fêtes de la science 2021

The players involved in the Chemistry Research Department participate in the science-society dialogue through a wide variety of mediation events:

• Supporting scientific events.

• Animation of social networks.

• Participation in radio broadcasts, events, meetings and debates between scientists and citizens to disseminate scientific and technological innovations (science festival).

• Promotion of chemistry in schools and high schools through a strong involvement in physics-chemistry group of the IRES (Institute of research in science education of the University of Montpellier).

• Democratisation of scientific knowledge through art via partnerships with various artists within the COSA group (science and art connection) initiated by the ICGM.

• Make science more visible in the public arena and to promote its understanding through scientific mediation actions involving all audiences, especially those who are more remote for geographical or socio-cultural reasons.

• Help all people, especially young girls, to discover and value scientific and technical disciplines, courses of study and careers.

• Promote dialogue between science and society with the help of associations and also with student associations from chemistry Departments of the University of Montpellier (allchimie, LAAB).

• Support projects that encourage the development and structuring of interfaces between scientists, decision-makers and citizens.

• Contribute to the development of scientific, technical and industrial culture.

• Promote closer ties between researchers and mediators.

The players involved in the Chemistry Research and Training Departments participate, among others, in the chemistry olympics, the science festival, fêtes de la science, the researchers' night and lead numerous scientific workshops (the impact of phytosanitary products on bees, nanosciences and nanotechnologies in the biomedical field, perfume chemistry, formulation workshops, sensory analysis workshops, molecular modelling presentation, How to invent new pharmaceuticals while sitting in front of your computer? What is your favourite chemical element and why?).

Many players involved in the Chemistry Research Department (students, doctoral students, researchers) are involved in organisations or associations with a regional, national and international impact on society.

At the time of publishing this white paper, we have learned of the death of Dr. Catherine Bied. We would like to pay tribute to this kind-hearted woman who was involved in the association she created, «Les Moléclowns», which put on fun and interactive shows that introduced young schoolchildren to science (6-9 years old). She also ran Chemistry and everyday life stands for the general public.

THE UNESCO SIMEV CHAIR

Using membrane technologies to offer drinkable water

Attached to the National graduate school of chemistry of Montpellier (ENSCM) and supported by the European Membrane Institute, the SIMEV Chair (Membrane Sciences Applied to the Environment) is an international university partnership, labelled by UNESCO since 2004, contributing to the UN Sustainable Development Goals, SDGs 4, 6, 7, 11 and 17. Science, technology, engineering and mathematics (STEM) are powerful tools to promote approaches to water conflict prevention and to offer drinkable water to population in need. Indeed, its STEM projects combined with participatory tools integrate local players, communities and the diversity of scientific experts at the Chemistry Research Department to develop effective local solutions to water issues. SIMEV leads university network of more than 20 institutions (Africa, Latin America, Asia), associated with technical and social stakeholders in the field.

SIMEV is also involved in capacity building programmes valuing membrane sciences by setting up Membrane Science and Technology Thematic Schools (more than 17 since 2004) based on concrete local and social water issues reported by the country host (industrial, agricultural, mining contaminations...).

This approach helps mobilising universities, government, communities, NGO´s and industrials intervening in the country on conflicts faced on the ground. SIMEV created the INOV'EAU network, which gathers 3 remotely connected technological platforms dedicated to training and research; they are located in Ouagadougou (Burkina-Faso), Kénitra (Morocco) and Montpellier (France).

Through the application of membrane technologies, the R&D projects supported by SIMEV enable the implementation of water treatment units in response to the needs of local populations (Senegal, Morocco), developed in collaboration with industrials.

The SIMEV Chair is also developing its activities in collaboration with other major UNESCO programmes such as the IHP (International Hydrological Program: it is a «member of the water family») or the Associated Schools network (Lycée Jean-Baptiste Dumas d'Alès in the Gard department).

The Chair is very attentive to problems linked to global change and recently participated in the «Youth for the Rhine» project, which aims to motivate the younger generations in the Rhine basin to solve several major societal challenges in Europe: adapting to climate change, in terms of water, food and energy management. Thus, SIMEV supported a partnership between the Erasmus mundus master students (membrane engineering for a sustainable world) and this European initiative to bring awareness on water quality in Rhine basin.

Similarly, the highlight of its activities in 2020 and 2021 was its participation, together with the Chemistry Department, at the «Geneva Peace Week 2020 and 2021», an international congress dedicated to the promotion of peacebuilding practices and research. It presented a plenary session on the theme: «Beyond Water: Science Diplomacy for Local Conflict Prevention» showing examples of its work in the field and how members are taking action to prevent water-related conflicts, build resilience and trust within local communities. SIMEV also participated and published an article in the white paper on environmental peacebuilding of the Geneva Peacebuilding Platform, the resource centre for enhanced peacebuilding. It links the critical mass of stakeholders, resources and expertise in global peacebuilding.

CONNECTING SCIENCE & ART-COSA

The acceleration of scientific and technological advances presents a whole host of questions about the society of the future (cloning, augmented human beings...), which artists are seizing, playing a scouting role, in the same way as researchers.

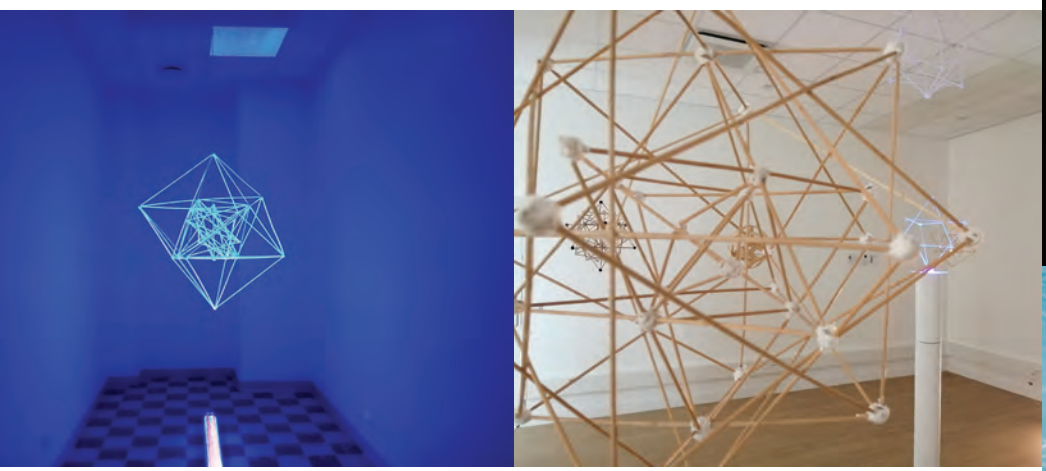
In this respect, it is important to bring them into dialogue around projects that question our relationship to life, energy, the connected habitat and the environment in order to suggest new presentation methods and aesthetics of knowledge in connection with civil society, taking into account non-academic knowledge.

Created in June 2016, the Connexion Science & Art (COSA) Group brings together the disciplines of chemistry, electronics, architecture and fine arts. The union of the Charles Gerhardt Institute Montpellier (ICGM), the Institute of Electronics and Systems (IES), in partnership with the École Nationale Supérieure d'Architecture de Montpellier (ENSAM) and Mo.Co École Supérieure des Beaux-Arts (MoCo-ESBA) has seen the emergence of an original and creative collective.

The COSA's missions are to:

- Conduct reflective work and experiments in Research, Science and Art,
- Develop strong interactions between artists and scientists,
- Share knowledge and practices,
- Encourage shared projects with these overlapping topics.

In order to do this, it offers an immersive experience into the research units through visits to laboratories and technical platforms and meetings with researchers. It organises and runs themed events, evening screenings/debates, conferences, exhibitions, specific workshops (biomimetics, sound matter) open to the public in collaboration with the Maison des Étudiants Aimé Schoenig and the University of Montpellier's Art and Culture Department.



Exposition de Franklin Bault
«Lumière Matière»

Pièce Folles Alliées
Photos Christian de Héricourt

Actions in favour of the United Nations Sustainable Development Goals

Supporting resilient & sustainable future models of society

Historically, the Chemistry Research Department has always developed its research, training and valorisation actions around big socio-economic issues.
Since its creation in 2007, it has worked on issues related to energy, the valorisation of natural resources and the circular economy, sustainable chemical processes, health and the protection of people. As such, its aims fit perfectly within the UN's 2030 Agenda for Sustainable Development Goals and within the pillars of the MUSE I-SITE. This section aims to show the special attention paid by the researchers to fit within the I-SITE's objectives «feed, care and protect» and those of the SDG.

IBMM Institut des Biomolécules Max Mousseron

Research at IBMM is integrated in SDGs such as Good Health and Well-Being, Responsible Consumption and Production, Life Below Water and Life on Land.

Strongly positioned in the I-SITE MUSE on the «feed and care» pillars in the fields linked to agriculture, the environment and health, the IBMM has already won 12 funded projects (10 research programmes, 2 international programmes). It actively participates in the promotion of Technology Platforms in direct connection with its research activities, including in particular the University of Montpellier's Laboratoire de Mesure Physique and Synbio3, led by IBMM personnel.

The research activity that fits within the **«Feed» pillar** is illustrated by flagship projects such as:

• The synthesis and identification of plant-based fats (omega-3 fatty acids: phytoprostanes, neuroprostanes) with cardioprotective, anti-inflammatory and neuroprotective activities used in nutrition, as dietary supplements and excellent clinical biomarkers and for the plant-based field.

• The study of the nutritional effects of wholegrain and coloured Camargue rice on fructose-induced metabolic syndrome and blood pressure reduction (collaboration with the University of Glasgow).

• The identification of new varietal thiol precursors and mechanisms revealing the aromatic potential of wine during fermentation (partnership with the company Nyseos).

The **«Care» pillar** is at the heart of the skills developed by the IBMM's biology and chemistry teams, through Chemistry for Health and Materials for Medicine:

• The invention of a «Nanobiosensor» to quantify kinase activity by fluorescence imaging in cancer cell cultures (Small 2021, ANR NanoMultisens) is part of an innovation programme in oncology (MATWIN SATT Conectus in collaboration with the Laboratoire d'Innovation Thérapeutique de Strasbourg).

• The development of 3D printing technology for regenerative medicine in the treatment of myocardial infarction (CardioPatch Interreg Sudoe project).

• The discovery of the involvement of serotonergic receptors and the synthesis of inverse agonists synthesised in a green chemistry concept, for the treatment of neuropathic pain, a chronic disease that has not been treated to date (Progress in Neurobiology journal, French-Polish collaboration).

• The development of molecules potentiating the beneficial effects of polyphenols and Omega-3s for their cardioprotective effects.

• The synthesis of lipophenol conjugates capable of reducing the oxidative and carbonyl stresses involved in age-related and genetic macular degeneration Stargardt's disease (article in «Nutritional Insight», specialist in nutrition and biomedical science, collaboration with the Institute for Neurosciences of Montpellier).

• The development of a nucleic acid-assisted self-assembly method of cationic porphyrins to generate light-sensitive siRNA nanoparticles, for a dual therapy application of siRNA + PDT on cell cultures (NanoMedSyn start-up).

The development of biocompatible compounds that can be activated by the absorption of one or two photons, enabling the detection, labelling and destruction of cancerous cells for an effective anti-cancer duo (collaboration with the ENS Lyon chemistry laboratory and the CEMCA laboratory in Brittany).

• The implementation of biochemical and biophysical approaches to resolve the structure of ghrelin (peptide hormone) linked to its receptor and synthesise new ligands; ghrelin being involved in the secretion of growth hormone, appetite, glucose homeostasis, drug and alcohol addiction, depression or certain cancers (PNAS 2019 journal, collaboration with the Institute of Pharmacology and Structural Biology of Toulouse and Brian Kobilka's team at Stanford University).

• The purification and characterisation by the L-protein involved in the replication of the Ebola virus (Nucleic Acids Research, collaboration with Oxford's STRUBI laboratory).

• The identification of a peptide (P42) capable of directly influencing neuronal plasticity and activity for the treatment of Huntington's disease, a neurodegenerative disease (collaboration with the laboratory of Molecular Mechanisms in Neurodegenerative Dementias MMDN of Montpellier).

• The synthesis of a pseudo-peptide agonist compound of the ghrelin receptor, used orally to induce the secretion of GH measured by blood sampling for the diagnosis of growth hormone deficiency (marketed by the company Æterna-Zentaris Macrilen™, partnership with the company Europeptides, European project Eureka no. 1923).

• The development of reversible mRNA cap methylation in the control of its stability (Nature article) to develop new anti-cancer therapies (collaboration with Samie Jaffrey from Cornell University).

• The design, synthesis and biological evaluation of a new type of biomimetic material, inspired by collagen for stem cell encapsulation and 3D bioprinting with applications in regenerative medicine and tissue

engineering (Materials Today, collaboration with the ICGM and the Institute of Regenerative Medicine and Biotherapy in Montpellier).

• The synthesis of urolithin C, a polyphenol metabolite, which stimulates insulin secretion in a glucose-dependent manner and has anti-diabetic properties (SATT AxLR maturation project).

• The discovery of new antibiotic compounds using the latest high-resolution mass spectrometry technologies (partnership between Deinove, LMP and IBMM, financed by the Occitania Region and Europe, ERDF, €1.2M over 30 months).

Research around the **«Protection» pillar** is focused on projects such as:

• The aim of the CO_2Mec project is to use the formidable potential of mecanochemistry (the use of mechanical forces in chemistry) to capture and enhance CO_2.

• The development of an elicitor peptide designed and tested in the field has made it possible to develop an entirely biodegradable and bioassimilable product for the natural protection of vines (partnership with the company De Sangosse).

• The MayBeBee artists' collective project «Est-ce aimer?» [Is this love?] (I-SITE MUSE funds) aims to raise awareness of art among the university community by highlighting the scientific research on bees carried out at the IBMM through «the chemistry of feelings» on a molecular scale, the construction of a relationship between two beings, and sustainable cohabitation between two societies negotiating the same space.

• Flipper, the «robot hoover» (developed by the LIRMM) captures rare images of the deep sea in real time and collects medicinal shellfish in the Mayotte lagoon, while preserving habitats, without any time or depth constraints. The shellfish collected are cone snails whose venoms have therapeutic virtues that are being studied at the IBMM.

• A partnership has been developed with the company MEDITHAU for the extraction and valorisation of natural raw materials (plant-based and aquatic) via the identification of compounds present in mussel byssus.

• The study of tardigrades and their resistance to extreme conditions, in order to understand their capacity to survive in the most hostile conditions as living crystals (totally dried out and devoid of metabolism) and to «resuscitate» after rehydration.

• The design of intra-uterine medical devices in treating mechanical female infertility as part of the ANR ANTISYN project, generated the creation of the start-up Womed (Grand Prix i-Lab 2018, LR region Chercheur d'Avenir prize 2013, collaboration with the Gynaecology-Obstetrics Department of the CHU de Nîmes, SATT AxLR maturation programme 2016-2017).

ICGM
Institut Charles Gerhardt Montpellier

The thematic fields explored within the ICGM fit harmoniously into the SDGs such as Good Health & Well-Being, Affordable and Clean Energy, Responsible Consumption and Production.

Its research in Chemistry also meets the expectations of the 3 pillars of the MUSE objectives with a very transversal positioning in the following societal issues:

• Materials for energy, imaging and information storage.

• The valorisation and conversion of renewable resources.

• The protection of humankind and its environment.

Its scientific project aims to create functional materials through the implementation of atomic and energy-efficient chemistry, to characterise them and describe their properties from the nanometric scale to that of systems, to evaluate their performance and to incorporate them into devices for use.

On a fundamental level, the ICGM's priority is to ensure its identity at the highest international level in the following five thematic areas.

1. Soft chemistry and molecular self-assembly for the preparation and multi-scale structuring of organic, inorganic, hybrid and bio-based materials.

2. Macromolecular chemistry and advanced polymers.

3. Surface functionalisation, interfacial chemistry and physical chemistry applied to solid state electrochemistry, adsorption and catalysis.

4. Quantum chemistry and modelling of molecular properties to system properties.

5. Solid state chemistry and crystallochemistry.

In addition, interactions with solid state physics, soft matter and nanoscience feature particularly in the ICGM's research. Interaction with biologists is also highly developed through research on the expected properties of molecules or materials (active principle, drug delivery, biomaterials) in the context of severe or chronic pathologies (cancer, inflammation, tissue engineering).

Besides research developed at the highest level of European and international competition, the ICGM's work draws its originality from unique transdisciplinary synergies in modelling/experimentation and materials/systems, made possible by the Institute's rich scientific potential, a proactive policy of mutualisation and very active scientific leadership.

The launch of MUSE has resulted in the ICGM funding a research project on materials for integrated optics applied to viticulture. In addition, the ICGM is a partner with the IEM in a project on the decontamination of water by molecules for pharmaceutical use. Finally, in partnership with CEA Marcoule, the ICGM is involved in a project on depleted uranium-based materials for electro-chemical energy storage.

The ICSM's mission is to be the unifying link within the Chemistry Research Department around separation chemistry, aiming to increase the excellence of the teams and to respond to the more specific SDGs on affordable and clean energy (SDG 7) as well as responsible consumption and production (SDG 12) via the challenges of sustainable nuclear energy and a rational circular economy.

The main strength of the ICSM is to develop an integrated R&D approach from fundamental research to exploratory R&D in separation chemistry. The Institute has the ability to make complete offers including the physico-chemical characterisation of formulations and materials for separation chemistry, interpretation of results and the related multi-scale modelling. This is possible thanks to the complementary skills and high level of expertise of the ICSM staff, combined with exceptional experimental capabilities. The ICSM has state-of-the-art testing and characterisation facilities, which it is still striving to develop through a sustained investment policy. Frequent access to major instruments such as SOLEIL, ESRF, LLB, ILL and GANIL complements the Institute's microstructural study resources and enables it to propose and carry out high-performance studies. The ICSM's location in the Occitania region, next to the Marcoule site, is vitally important because it allows close contact with the CEA's R&D players involved in separation chemistry. Finally, the proximity with the Chemistry Research Department's teams also allows the effective sharing of the technical resources offered by the hub's various platforms.

Building on the synergies established between the partner teams of the Chemistry Research Department and LabUM chemistry, the ICSM wants to contribute to greater integration of disciplines and acquire the means to initiate new collaborations with biology, agronomy, environmental sciences and digital sciences. Strengthening the links between disciplines and reinforcing the role of research in training are likely to provide solutions to the challenges of the chemistry of the future, in a context of internationalisation, intensified competition and rapid technological change. In collaboration with the Universities of Strasbourg and Avignon, implementing a short extraction and separation cycle has made it possible to obtain for the first time a Pd catalyst (Suzuki reaction) from WEEE on a laboratory scale. The catalyst's performance was shown to be as good as that obtained with commercial catalysts.

As such, chemistry at the ICSM is unique in its diversity, covering all the thematic fields of chemistry (theoretical, organic, bio-organic, mineral, polymers, materials, processes...) and in its multidisciplinary nature, with a very strong involvement in research at the interfaces. Coupled with strong fundamental research, these assets will enable it to take up the I-SITE MUSE's three major societal challenges by developing devices, processes, materials and molecules for the benefit of humankind and its environment.

Institut Européen des Membranes

Due to the IEM's thematic focus, the work and actions developed are by nature related to or integrate a large number of UN Sustainable Development Goals from the project design stage onwards. Among these, SDGs 2, 3, 6, 7, 12, 14 and 16: zero hunger, good health and well-being, clean water and sanitation, affordable and clean energy, responsible consumption and production and life below water, are mainly concerned to varying degrees in projects in which these SDGs are generally interconnected.

In general, several projects are being developed in the field of gas separation and production for energy applications. For example, the treatment of gases under aggressive conditions is being studied as well as H_2 production and CO_2 reduction.

In terms of health, studies are being carried out on the use of membranes for bone replacement and the controlled diffusion of active ingredients.

Broader studies relating to the circular economy are also being carried out using coupled separation and membrane processes to valorise waste.

The «Water» theme is probably the most developed in order to contribute to a better and more sustainable future for all. In this field, the global challenges are linked to poverty, climate and environmental degradation. These objectives are interconnected and have given rise to the nexus: Water, Energy, Environment, Food. Thus, we no longer talk about wastewater treatment plants (WWTP) but instead resource recovery centres (RRC), and instead of «reusing treated wastewater», we use the term «reusing or recycling water». This water is a source of secondary raw materials and its treatment is oriented towards the search for circular economies. The objective is therefore to valorise these alternative sources of water, matter, nutrients and energy by integrating more sustainable processes, cleaner water and valorised resources, themes on which the IEM has a strong focus, whether it be concerning anaerobic membrane processes for a positive energy treatment chain through the production of biogas, or the production of treated wastewater likely to have a second life, for various uses (irrigation, drinking water treatment...). As such, the unit's skills in membranes and associated processes: Ultrafiltration-Nanofiltration, Ultrafiltration-Reverse Osmosis or couplings (advanced oxidation-membrane or enzyme-membrane reactions) are fully used in a number of projects, including in connection with local authorities.

Several projects also concern the desalination of sea water, whether for the production of drinking water for all, using renewable energies to power water purification systems or in the field of innovative materials, with artificial water channels.

The treatment of oily effluents and micropollutants present in water (drugs, endocrine disruptors, pesticides...), emerging but no less important themes, are obviously also at the heart of our concerns, with the objective of allowing the effluents to be discharged into the natural environment or the water to be reused, i.e. closing the water cycle. Similarly, the selective extraction of metals of interest (heavy metals, rare earth metals, or platinum group metals) from industrial effluents is also a priority subject for environmental and economic reasons.

The IEM is also the supporting laboratory of the SIMEV UNESCO Chair, whose activities and objectives are perfectly in line with several of the UN Sustainable Development Goals. Since its creation in 2004, the researchers, staff and members of the design and prototyping workshop have been developing integrated research, training, information and networking activities within the UNESCO Chair, oriented towards Southern Hemisphere countries, in the field of membrane science applied to the environment.

6 VALORISATION & START-UP

From the bench to the market

The research developed within the institutes of the Chemistry Research Department has led to important advances and contributes to the technological and scientific attractiveness of SMEs and VSEs in the strategic fields of human health and protection, sustainable chemistry processes and the energy and ecological transition.

The valorisation of research activities is also essential for the creation of wealth within our region. Supported by its development structures (Carnot Institute, CEA and regional agencies), twenty-four startups have been created since 2009, and more than half of these startups are still located in the region. Others have been acquired by multinationals. This section lists the efforts made in favour of regional socio-economic development.

FEW FIGURES ABOUT INNOVATION & DEVELOPMENT

24
Startups since 2009

22
Active licenses

>200
Patents filed since 2014

>280
Contracts with private partners since 2014

2
drugs marketed (Macrilen™, Sebivo™)

4
ANR joint laboratories

65
CIFRE agreements since 2014

IBMM Institut des Biomolécules Max Mousseron

Since it was created, the IBMM has been involved in a rather exceptional process of valorising its research with several innovation prizes, 2 molecules on the market, partnership research and technology transfer activities. It is one of the leading French chemistry institutes in terms of the creation of startups, with 15 companies created in the fields of drugs, health and cosmetology. Over the last six years, the IBMM has registered more than 53 patents, including 14 licences, 60 contracts with private companies and 13 CIFRE supports. The IBMM currently hosts 5 companies on its premises, thus encouraging the culture of innovation, particularly for students. It is also involved in a LabCom project (ANR) with the company Calixar from Lyon (Chem2Stab). IBMM is a member of the Carnot Institute Chemistry Balard Cirimat and offers companies privileged access to the IBMM's scientific skills.

Marketing of the drug Macrilen™. As the result of the IBMM's expertise in peptide analogue synthesis (Macimorelin), Macrilen™ received marketing authorisation from the Food & Drug Administration (FDA) in January 2018 and from the European Medicines Agency (EMA) in January 2019, for the diagnosis of adult growth hormone deficiency (AGHD). This product is marketed by Novo Nordisk. This compound is also in clinical phase for the treatment of cachexia.

Development of a new drug against hepatitis B. Telbivudine (Sebivo TYZEKA™), a nucleoside analogue resulting from IBMM research, is marketed by Novartis for the treatment of hepatitis B. The European Patent Office rewarded this discovery in 2012 with the Inventor Award.

Medical device for women's health. The company Womed, which grew out of the IBMM's work in the field of bioresorbable polymers, has just obtained CE marking for its first product, Womed Leaf. This innovative medical device aims to prevent the formation of intra-uterine adhesions following intra-uterine surgery, which are the cause of miscarriages and fertility problems. This is a major advance that could make it possible to treat other conditions, including endometriosis.

RECENT EXAMPLES OF START-UPS CREATED AT THE IBMM

MedinCell
Hydrogels for the administration and progressive delivery of active ingredients.

COLCOM
Nanotechnologies applied to human health (Lysine grafted dendrimers)

ARTHUR DUPUY
Creation of olfactory entities (logolfs), perfumes, aromas and cosmetics.

GENEPEP
PEPTIDE & PROTEIN SYNTHESIS
Custom synthesis of peptides, small modified proteins (amino acids, stable isotopes, fluorophore chemical markers and post-translational modifications: glycosylation, phosphorylation, methylation).

NanoMedSyn
Bioproduction of recombinant enzymes for the therapy of lysosomal diseases. Vectorised nanoparticles for photodynamic treatment of prostate cancer.

HALLSTAR
New generation of active ingredients known as «Oleophytoactive» ingredients resulting from an extraction according to an innovative and efficient green process, without chemicals or organic solvents.

womed
Design, production and marketing of innovative medical devices in the field of gynaecology.

ICGM
Institut Charles Gerhardt Montpellier

With regard to interaction with the socio-economic world, the ICGM wishes to illustrate its know-how and the synergies that can be developed within the ICGM through its partnership with the company Bulane SAS (SME). This example is remarkable for its scientific content and its outcome. Overall, this project has all the advantages associated with the research ecosystem: production of new knowledge, acquisition of IP, technology transfer and long-term partnership with an SME developing its activities in a high-growth potential market. The ICGM has the ability to comprehensively address scientific issues, from molecule to device, in the field of hydrogen vectors, and more particularly the components of fuel cells and electrolysers, that has led to this interaction and finally established its success.

bulane The ICGM supports Bulane with its R&D issues related to electrochemistry and processes, and more generally on the improvement of energy efficiency and the quality of the gases produced. The problem of nanostructuring of electrode materials and its impact on electro-chemical kinetics was addressed as part of a CNRS/Bulane doctoral thesis and a second thesis supported by ADEME. These studies led to the formulation of original composite electrodes with optimised surface properties, for which a patent has been filed. The manufacturing process has been scaled up and the excellent gas production and lifetime performances have been validated as part of a maturation project supported by the SATT AxLR and the LR Region. These innovations, combined with a particular electrode design, a formulation and use of high-performance electrocatalytic materials, a multifunctional mechanical assembly, and finally a high power density, have led to the development of a product called dyomix Mobile (35 kg), which is now intended for heating and plumbing contractors. In order to continue its strategic progression in the oxyhydrogen flame market, Bulane now wants to address the emerging markets it has identified and to put itself in a position to respond industrially to the needs of future electrolyser markets, including for the public (boiler hybridisation). The strategy aimed at acquiring the technological building blocks necessary to lift barriers allowing the development of these new products is the basis of the MATELHO LabCom project supported by the ANR but also by the ADEME and the Occitanie Region.

ICSM

The ICSM, in charge of development at TRL (Technology Readiness Level) 1 to 3, was created to interact with the various R&D departments of the CEA, which are mainly in charge of TRL 2-3 to 6-7 in the nuclear field and, for research outside the nuclear fuel cycle, to turn to the development tools set up by all the supervisory bodies (SATT AxLR, CNRS Innovation, CEA Tech).

Since its creation, ICSM contributed in collaborations with the CEA on «technological» research projects (upstream and downstream of the cycle), through the partnership policy encouraged with companies (AREVA/Orano, SOLVAY, VEOLIA, Morphosis, Arcelor Mittal, New Tech, Adionics, Sovamep, OCP, TATA) or with other academic partners including the University of Montpellier, particularly in the field of recycling (Labex CheMISyst) or in the context of partnerships with the ANR (Oleos, TND, CTI, Woellner). Similarly, recognition of the Institute's skills in the fields of materials chemistry, analytical development in environmental electron microscopy, X-ray scattering, mesoscopic modelling and chemistry for sustainable development led to several requests for expert missions in these different fields (CEA, IAEA, Extracthive...). About 30 service contracts (ICP analyses, microscopy, NMR...) were carried out as part of projects outside the ICSM, CEA or industry (EDF, MELOX, VEOLIA, Torskal, SEMTec, St-Gobain, Cis-Bio, Faurecia).

In terms of patents, 33 have been published in the last five years and between 5 and 10 projects are studied each year. The ambition of the «Recycling of strategic metals» component has thus made it possible to organise the prospect of applied research by encouraging collaboration between teams from different research organisations and industrialists (SOVAMEP, TND, Veolia, CTI...) so as to encourage the emergence of complete industrial recycling sectors. To this end, several levers essential to initiate, develop and achieve the objectives set have been used, from the analysis of waste deposits containing potentially valorisable materials, to the implementation of treatment and recycling processes (specific programmes undertaken by the ANR, PIA, H2020, ERAMIN, SCARCE, CEFIPRA, CEA Valorisation programme, Region), but also by funding from demonstrators (by SATT AxLR).

Project SILEXE Strategic metal recycling in Ionic Liquids by Extraction and Electrodeposition process.

Through successive funding initiated by the Labex project (EMILIE) in 2012, the ANR CD2I project (SILEXE), and following the development of SATT AxLR, in collaboration with the company TND and the Institut Jean Lamour (IJL), a process for recycling tantalum, gold, and palladium contained in electronic cards was developed using commercially available ionic liquids.

SANOU KOURA
Critical Metals New Mining

The startup «SANOU KOURA», created in 2019, aims to raise the funds required to install a recycling plant (site located in Donchery) which would be the first in the world to recycle tantalum, in addition to other recoverable metals (palladium, gold, silver and copper).

Project «CelDi» Cell for monitoring reactions at the solid/fluid interface under a scanning electron microscope.

NewTec Scientific

This project was supported by SATT AxLR and was carried out by ICSM and NewTEC Scientific (based in Nîmes) between 2016 and 2018. It aimed to develop a test cell dedicated to the direct study of reactions at solid/liquid or solid/gas interfaces, used in any type of scanning electron microscope (SEM). This cell makes it possible to work with massive solids during renewal of the fluid in contact with the solid. An industrial demonstrator became operational and serves as the basis for the launch of the commercial phase of this device (carried by the company NewTEC Scientific). This work has been patented.

Project «FurnaSEM» Manufacturing of a family of high temperature furnaces for SEM.

This project, supported by the Occitania Region as part of the «READYNOV - Aerospace and Advanced Industries», brings together the ICSM and NewTEC Scientific for the development a series of SEM furnaces that cover the range 25°C-1450°C in any type of atmosphere. The first FurnaSEM 1000 furnace is now on the market, and offers performance that is unattainable by competing furnaces. Unprecedented high-temperature experiments (such as 3D surface imaging or low-voltage image recording under gas) can be performed. This work has been extended and now involves active collaboration with the Czech company Crytur to develop a unique high-temperature backscatter electron detector. The combination of the FurnaSEM furnace with this detector allows for the recording of images, showing directly, at high temperatures, the evolution of the chemical composition of a sample during transformation, on a sub-micrometric scale.

Reconstruction of a transmission electron microscope (NewTEM project).

In partnership with NewTec, this project aims to completely rebuild the electronics (servo-controls, lens control, high voltage control) of an old TEM (1980) and to ensure its control by software developed in-house. The aim is to enable this TEM to operate with optimal performance, reliability and manoeuvrability (complete control of all the electronics means its configuration can be adapted to the new imaging or diffraction techniques). The «NewTEM» is now operational. The promotion of this work in the context of a transfer of skills or the creation of a start-up company is currently being evaluated.

Institut Européen des Membranes

Since its creation, the IEM has been developing research based on concrete problems linked to societal concerns, and has always maintained strong links with the industrial world. Thus, over the last five years, around 60 research and development contracts have been established directly with industry, i.e. excluding ANR or FUI projects in particular, as well as 9 CIFRE agreements. Thus, the IEM collaborates almost exclusively in research projects with numerous large groups as well as SMEs and start-ups, including: Total, Areva NC, Alstom, General Electric, Safran, Snecma, Herakles, Peugeot, Citroën, Saur, Suez, Air liquide, Exxonmobil, Saint Gobain, Céramiques Techniques Industrielles, Orelis, Firmus, Mascara nouvelles technologies, Pierre Fabre, Sanofi, BASF, Arkema, Solvay, Sikemia, Zodiac aerospace, Chanel parfums beauté...

The IEM also has a strong promotion policy reflected in particular by the filing of 21 patents over the last 5 years and the support of the SATT AxLR for 6 promotion projects. The IEM's dynamism is also reflected in a growing entrepreneurial spirit among IEM staff through the recent co-creation of several start-ups.

Signature of a framework contract with Veolia Water Technology (VWT).

A contractual partnership has been created in 2018 with a world leader in water treatment technologies. It aims to carry out joint studies on several topics of interest to both parties. This agreement concerns the substantial development of materials and processes for water filtration in the context, in particular, of advanced industrial applications: ultra-pure water used in pharmaceuticals and industry, desalination of sea water, filtration of pesticides such as glyphosate and metaldehyde, and real-time monitoring of the physical state of membranes in use...

ANR Joint Laboratory «M-LAB» with the company POLYMEM.

The IEM and POLYMEM-Repligen group, an manufacturer of polymer hollow fibre membranes for water and effluent treatment, have been awarded an ANR «M-LAB» joint Laboratory. The objective was to investigate the fundamental mechanisms involved in the manufacture, use of the membranes during the operation of the membranes on site. Thanks to support and funding from the Occitania region for the GRAINE project (36 months), the partnership continues through the joint Laboratory for Advanced Membrane Manufacturing Processes (M2Lab).

Pre-industrial scale-up of a process for the production of drinking water.

The WATERLAND project, supported by private investors and the CNRS innovation, is devoted to the manufacture of biomimetic membranes for seawater desalination. This is a process that could remove technological and energy barriers to meet the challenges of water supply in water-stressed countries.

RECENT EXAMPLES OF START-UPS CREATED AT THE IEM

sweetch ENERGY

Nanotechnologies and materials for electricity generation.

Created in 2015, it aims to produce electricity by exploiting the differences in salinity between two waters, for example the fresh water and salt water of estuaries.

bio 4 life

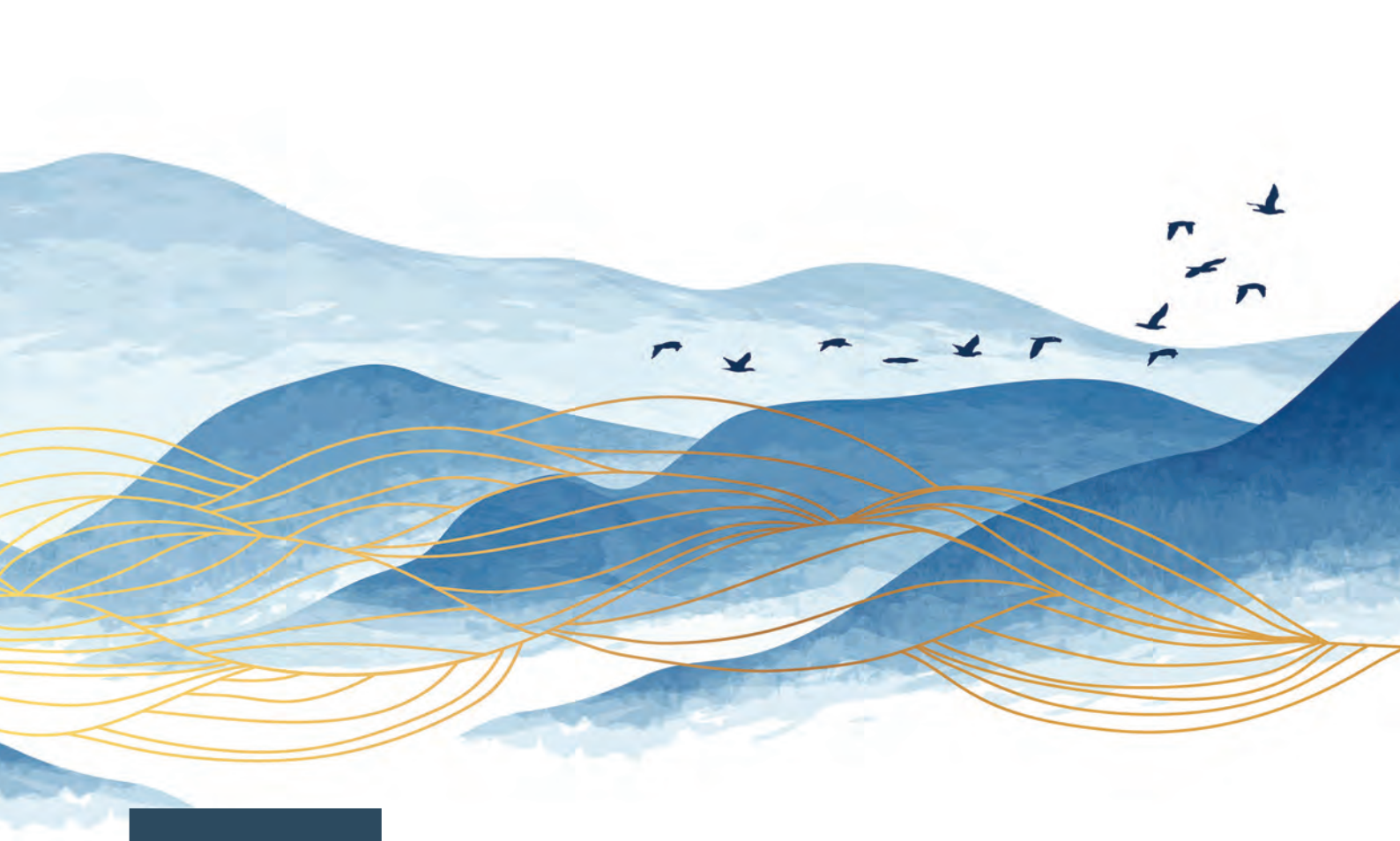
Injectable biomaterials for the treatment of bone metabolism disorders.

Created in 2019, it develops injectable phosphocalcic cements for bone repair (osteoporosis, cancer...).

NEXTMAT 3D
FROM MATERIALS TO ADDITIVE MANUFACTURING

3D printing for dental surgery.

Created in 2022, it aims to offer printed osteo-mimetic implants in dentistry.



7 SCIENTIFIC PROJECTION & PROSPECTING

Reflecting on technical, educationnal & research engagements

Despite the efforts made by those within the Chemistry Research Department in training, fundamental research, and research with a societal impact and development, the chemistry community is aware that many investments still need to be made and pursued in order to achieve the objectives defined by the I-SITE programme of excellence and the Ministry.

This section aims to present the reflections of the actors and students of the Chemistry Research Department, thus maintaining the diversity of individual and collective experiences specific to each research theme. These reflections on scientific projection and prospecting will be accompanied by examples illustrating the transformation of our sector. They are presented by institution.

These reflections will serve as a support for the Chemistry Research Department to construct activities and orientations, which will also be articulated around the pillars defined by the University of Montpellier in the field of (1) animation, communication, strategy and scientific prospecting, (2) partnership collaborations and structuring of research, (3) visibility and international influence, (4) the interface between training and research, (5) the scientific governance of the University, (6) participation in prospecting in terms of management of jobs and skills.

STUDENTS & ALUMNI

Testimonials

Habib BELAID

Master student in Materials Science at the University of Toulouse, he came to Montpellier for a Master 2 internship. PhD and Post-Doctoral Fellow at the IEM, he is now the founder of a start-up company.

«My training as a young scientist was rich in terms of the collaborations. During my thesis, I collaborated with surgeons at the University hospital, biologists, chemists, and with the private sector. The Montpellier ecosystem has a large network of scientists and development infrastructures that are always available so you can develop ideas and create the proof of concept. The regional economic agency has enabled us to create a start-up company «NEXTMAT 3D», particularly for dental reconstruction surgery.»

Simon CASSEGRAIN

Student from IUT in chemistry and Master degree at the University of Montpellier, he later did this Doctoral thesis at the ICGM. He is currently doing his Post-Doctorate abroad.

« I spent 5 years in what I consider my family, my scientific family! The dynamism of the laboratory, the working group, the listening and the supervision that I received all met my expectations. The PhD gave me an open mind. Now in Canada, I realise how lucky Montpellier is. In a small area, i.e. in less than 1 hour from one end to the other, all the skills are brought together on the I-SITE site. As well as their availability, the researchers are volunteers and wish to pass on their knowledge. The Master of Science in Chemistry (SASA) course was very rich and comprehensive. It allowed me to develop synthesis and analysis skills. Then during my PhD, the ED was welcoming. It is a real pillar of support for doctoral thesis, the team is available and always ready to listen. »

Raquel GUTIERREZ-CLIMENTE

Obtained a PhD in 2015 from the University of the Basque Country (Spain). Postdoctoral Fellow at IBMM and ICGM. She's currently working in the national environment agency.

«I arrived in Montpellier in 2019, after my first Post-Doctoral experience at the University of Technology of Compiègne. What surprised me most (even though I didn't know it at the time) was the University of Montpellier's MUSE project, or the number of projects between several partners of the University of Montpellier and the good working relationships between the different research institutes. The dynamism and research quality of the Institutes, as well as the people I worked with, made me enjoy these Post-Doctoral years despite the pandemic. Montpellier is the 5th city where I've had the opportunity to work as a researcher, and I would like to settle here! »

Elise GUERINONI

PhD student at ICSM. From Alsace, she did her preparatory classes in Strasbourg before moving to Montpellier. She was trained at ENSCM with a major in nuclear chemistry and environment.

Those are perfect conditions for a Grignard reaction! a typical chemist's expression. To understand its meaning, you need to know Victor Grignard, Nobel Prize in 1912. I fell privileged to access to such broad variety of chemical disciplines, in such historical city, Montpellier. Being trained from polymers'science to recycling of rare earth elements, my education helped me to get an open scientific mind-set. The knowledge sharing between generations is well established. I personally met life-changing professors and students. Now in Marcoule with chemist friends from all over France and beyond, Lebanon, China, Brazil..., I realise that studying in Montpellier was a chance and far from being limited to a geographic area. Finally, I need to explain to you the true origin of the Grignard reaction's expression. To succeed this method, you need to be in anhydrous atmosphere and what a better place than the weather of Montpellier!»

REFLEXIONS FROM CHEMISTRY STUDENTS AND ALUMNI

Visibility of the Chemistry Research Department

Continue to offer the diversity of subjects covered in the Bachelor's and Master's degrees in chemistry, clearly identified as an asset by external students.

Promote communication, welcoming and integration of young foreign researchers within the Chemistry Research Department and its scientific ecosystem.

Scientific activities

Strengthen scientific communication within the Chemistry Research Department and with the other departments of the University of Montpellier encourage exchanges and collaborations between young researchers.

University training adapted to the socio-economic sphere

Continue teaching at the interface between disciplines other than chemistry.

Develop discovery internship initiatives in the laboratory on the diversity of research themes to encourage vocations in chemistry.

Strengthen Master courses adapted to the needs of the private sector.

Offer visits to local companies to make young people aware of industrial needs and expectations.

Make students aware of opportunities in the research and private sector.

Skills management for young researchers

Develop the «soft» skills necessary for good scientific communication, project management and employability of doctoral students.

Raise awareness on the rights and duties of doctoral students (scientific publication, ethics, integrity, transparency).

Mobilise doctoral students to participate in local and national scientific activities.

Promote activities to share knowledge with the public.

Improve access to mentoring for doctoral students in general and more specifically for doctoral students facing problems in interdisciplinary research.

Promote exchanges between doctoral students and the industry in order to facilitate recruitment, thus removing obstacles to employment for young graduates.

Propose specific training courses adapted to the real needs of doctoral students working in an interdisciplinary way.

Continue to raise awareness of entrepreneurship.

THE CARNOT INSTITUTE CHEMISTRY BALARD CIRIMAT

Anticipating and creating solutions based on the needs of the land.

Strengthened by a broad scientific culture in the fields of chemistry, materials and processes, and its numerous multidisciplinary academic links, the Carnot Institute Chemistry Balard Cirimat will reflect on strategy to better understand the technological needs of society and to anticipate changes, in order to define in a relevant way its scientific resourcing programmes. Its resourcing and partnership research will also be oriented in the coming years to contribute to successful energy transition (materials for energy storage and conversion, use of hydrogen), benefiting human health (developing active molecules, medicines, biomaterials...), developing new materials and original shaping technologies adapted to the industry of the future (new functions, better durability, adaptation to digital manufacturing technologies...) and to the substitution of a chemistry, and substituting polluting processes with green chemistry (bio-sourced, bio-degradable polymers...). Its activity will therefore fit naturally into the key technologies identified in Occitania, but also at national level.

Integrating environmental responsibility into projects.

Since evaluating potential innovations must now have the greatest possible consideration of its impact on nature, and even its capacity to contribute to restoring balances disturbed by the excessive exploitation of resources or the massive production of pollutants, Chimie Balard Cirimat will integrate this dimension now more than ever into its project selection processes.

LABUM CHEMISTRY

Whether it is a question of nutrition, protecting the environment, or health, we must design products that are effective and resistant, but also non-toxic, degradable after use, and environmentally friendly. Through an integrative multi-scale approach taking on the strengths of the Chemistry Research Department, LabUM Chemistry, operational since 2020, proposes reinforced, transdisciplinary cooperation to support research projects on:

Innovative agriculture, food safety & environmental quality.

Designing active molecules and systems for environmentally friendly agriculture, studying and synthesising plant molecules useful for human health and recycling agricultural waste and using biomass as raw material.

Energy transition & environmental remediation towards an environmentally friendly society.

Providing complementary solutions for the decontamination, restoration and protection of the environment, eliminating and recovering waste. It aims to design systems capable of producing or storing clean energy, developing processes for the synthesis of molecules that are friendlier to the environment, developing processes for the treatment of contaminated effluents, and to set up processes for the reasonable recycling of recoverable materials.

Search of new treatments.

Human health in changing environments through an in-depth understanding of physio-pathological mechanisms at the molecular level, the design of active molecules, delivery, targeting and transport systems for targeted treatments, drawing inspiration from nature and also using living organisms for treatment. Based on the initiatives already carried out by chemistry within the I-SITE MUSE project and the structuring projects of the Montpellier site, LabUM Chemistry aims to catalyse interdisciplinary innovations for which chemistry provides breakthrough solutions and to train young researchers and to prepare them for the new challenges of our world.

PROSPECTS FROM THE RESEARCH ECOSYSTEM

Within the IBMM

Towards a unique site in Europe for the influence of chemistry in all its facets.

The IBMM is looking forward to a major evolution in its history with the move to the CNRS campus. Bringing together all of Montpellier's chemistry, it will be the most important research center in Europe, combining all facets of this discipline. The proximity of teams from different chemistry specialities and the grouping of technological platforms in a single location will be considerable assets for encouraging exchanges, collaborations, and the emergence of new projects at the interfaces. Interdisciplinarity will be strengthened by the geographical proximity to biological research institutes. This new synergy will boost our research into the design, synthesis, and biology of biomolecules and materials for health, well-being, and the environment.

Affirming the place of chemistry in the local ecosystem and promoting interdisciplinarity.

The Chemistry is the cornerstone that supports a coherent, scientific whole. Situated at the interface between other disciplines, it is an ally and an essential partner in responding to major societal challenges. In this content, the IBMM project is facing the great scientific challenges: (1) improving human health in changing environments, (2) promoting innovative agriculture contributing to food security and environmental quality, (3) fostering the transition to an environmentally friendly society. The urgent need to meet global requirements in terms of food, protecting the environment, and health means that technological innovation is essential. This innovation cannot occur without a significant overlapping of disciplines.

Pursuing scientific ambitions.

The work of the IBMM is motivated by major public health issues. The Institute will pursue its ambitions to (1) develop new technologies for the rapid synthesis of biomolecules and biomaterials, their analysis and characterisation, while considering their environmental impacts, (2) study the mechanisms of action of these biomolecules, their pharmacology in vitro and, for the selected compounds, to undertake in vivo studies through academic and industrial collaboration, (3) bring the most promising technologies and compounds into development.

Strengthening the links between research and training.

IBMM staff are heavily involved in university teaching (76 EC/180 permanent staff, i.e. 42% of permanent staff). It should be emphasised that these teachers often teach in several establishments and/or departments of the University. Their pedagogical involvement helps to break out of the isolated logic of traditional training. The strong link to research and teaching and the desire to break down the barrier between the laboratories and the students is illustrated by the involvement of IBMM staff in creating an SFRI Master's degree programme, IDIL, and its involvement in teaching units. Likewise, the IBMM contributes to training for companies through schemes such as UM or CNRS Formation Entreprises, with, for example: Mechanochemistry for an eco-friendly synthetic chemistry, Preparative HPLC applied to peptide purification, Peptides as a therapeutic modality.

Stimulating exchanges within the laboratories and institutes.

Seminars will continue to be organised allowing PhD students, post-doctoral students and masters trainees to present their projects and work. If the dispersion of the teams on several sites limits the organisation of internal seminars, regrouping in the Balard Research building will allow much more across-the-board activity for the whole of the IBMM, extended to the other institutes (ICGM, IEM and biologists of the CNRS campus).

Promoting scientific visibility.

The IBMM will continue to participate extensively in scientific activities, particularly at the interface between biology, by organising scientific days, forums, fairs, conferences for colleagues from other disciplines and for the general public (biomarkers, SIRIC, perfume fair, scientific experiment workshops during the science festival, radio broadcasts).

Promoting responsable research.

The research carried out at the IBMM must consider the major societal issues of our time, such as the environment, gender equality, the training of students and raising awareness of science among young people and the public. The IBMM has integrated into its projects measures to respond to the challenges of economic and sustainable development, as well as to societal questions concerning sustainable chemical processes, health, and the protection of humans. Through activities in secondary schools to present the profession of researcher and mentoring for female doctoral students, the IBMM is involved in promoting vocational and professional equality in chemistry.

Within the ICGM

To address academic challenges linked to major societal issues.

The project of the Department of molecular chemistry and materials of ICGM is contributing through molecular chemistry, structuring and shaping of materials to academic challenges and major societal issues of our century. Indeed, the project is seeking to serve humankind and sustainable development, by addressing: (1) environmental issues (decontamination of mobile radioactive elements, solar energy conversion, pollutant sensors, organocatalysis, homogeneous catalysis), (2) biomedical issues (bioactive molecules, biomate rials, formulation and controlled release of active ingredients, biological safety of nanoparticles, dynamic phototherapy, magneto- or photo-induced hyperthermia, imaging), and (3) related to information sciences and technologies (optoelectronics, organic semiconductors, thermoelectrics, magnetoelectrics, energy-efficient display devices, information storage).

To develop research projects based on societal applications.

The project of the Department of macromolecular chemistry and materials is focusing on the development of societal applications in the fields of Environment, Health and Energy. This desire to contribute to the circular economy of plastics, but also of critical metals, is well aligned with the development of ambitious projects developed at regional scale. The eco-design of biosourced polymers is part of this development axis. In the field of liquid effluent treatment, efforts aim at developing thermosensitive or photosensitive polymers or resins capable of complexing radioactive effluents or heavy metals. Fluorinated polymers are of particular interest in the energy field (fuel cells, Li-ion batteries) but also as electroactive polymers. Finally, to meet major public health challenges, the department is studying the design and functionalization of macromolecules dedicated to the formulation of therapeutic systems and in the context of targeted medical applications (e.g. tissue engineering).

To foster fundamental research combining environmentally friendly processes.

The project of the Department of porous & hybrid materials aims to develop new ways of elaboration of porous materials and hybrid materials including approaches more respectful of the environment. These approaches will allow to establish the structure-property relationships of the materials, necessary for the optimisation of their performances in the fields mainly of adsorption and catalysis. The projects that will be developed and that are related to materials engineering, will aim at controlling the condensed structures at the atomic or mesoscopic scales, the organisation and the dimensions of the pores, but also the morphologies and the functionalities of the hybrid materials and the porous materials. On the other hand, projects will be developed on the physical chemistry of solid/liquid interfaces in inorganic, hybrid or polymeric nanostructured materials. The main objectives are the understanding of the interactions involved and the organisation of the species adsorbed at the interfaces, the analysis of the competitive and/or synergistic effects between the surface chemistry, the interfacial water structure, as well as the adsorption and solvation effects.

To enhance understanding in the field of Energy.

Beyond the problems of synthesis, formulation and shaping, the project of the Department chemistry of materials, nanostructures, materials for energy focuses on the exploration of the physico-chemical properties of materials under specific operating conditions/constraints or application contexts. The projects will focus on 4 major themes: (1) chalcogenides and glasses, (2) multidimensional crystals and nanostructures with multiple functionalities, (3) oxide materials, (4) electrochemistry for energy. A major research focus of this department is the development of new electrode materials for post Li-ion, surface modification and «all-solid state» batteries, new proton or electronic conductive materials for fuel cells, electrolyzers and other electro-chemical conversion devices (with the objective of moving away from noble metals). The effort on the study and understanding of the mechanisms at the interfaces in storage and conversion systems will be accentuated. Emerging topics will be addressed such as, for example, the contribution of molecular chemistry for the design of new electrolytes and interfaces, single atom electrocatalysis.

To innovate in computer sciences for new predictive models.

The Department of theoretical physical chemistry & methodology focuses its research on three main application areas: physical chemistry of the environment, homogeneous and heterogeneous catalysis, and energy conversion and storage. In order to meet the challenges in these fields, the development of new theoretical models requires the identification of new descriptors, thus allowing experimental research to be directed towards a more rational design. The complementary nature of the expertise gathered within the department will be an asset to develop new innovative theoretical methods, to link the time and space scales characteristic of the different architectures studied, and to fertilize the theory/experiment collaborations.

Within the ICSM

Adapting research policies and sustaining successful models.

The distinction made since the creation of the ICSM between «understanding», i.e. demonstrating the predictive power of models based on first principles, and «optimising», i.e. demonstrating the feasibility of new chemical systems in selective extraction, thus including the principles of «green chemistry and green engineering», must be adapted to evolving research policies. The ICSM's scientific strategy will thus be based on the permanent adaptation of investment and skills management policies so as to preserve a good balance of research common to the CEA and the University of Montpellier, through its Chemistry Research Department and its research institutes. The success of the research developed at the ICSM will be possible thanks to the unique but complementary skills of each of the teams, which have become skills groups for the occasion. Some have multiple expertise that can be integrated into at least two of the three clusters.

Developing projects focusing on the circular economy and energy transition.

Certain parts of the programme in favour of the more sustained development of decarbonised energies, or certain major strategic orientations of the French nuclear power industry, offer a favourable framework in which the ICSM can take advantage of and continue to develop its expertise. Contributing to the challenges of the law with regards to energy transition for green growth, and integrating the concept of the circular economy, appears to be essential for the ICSM. This is particularly the case for the nuclear energy sector which has, as far as France is concerned, the possibility of extending the operating life of EDF's reactors beyond 40 years, and launching a new generation of fast neutron reactors in the longer term. These perspectives highlight the need to refine a cycle of fuel that will not simply be an extension of the existing one. In this context, research in the nuclear field perfectly integrates each aspect of the challenges of sustainable development and constitutes a tre-

mendous opportunity for innovation and progress in research, education, and industry. In the field of alternative energies, which also frequently involve «f» elements, the ICSM is in a similar situation, even though there are more players in fundamental research and R&D at the national level. Current policies regarding the anticipated recycling of strategic metals, but also of non-electrolytes (cellulose, lignin), and regarding environmental protection (clean processes, decontamination) offer a huge opportunity to use the skills present at the ICSM in processes that are well-understood and that can be optimised without experimental plans.

Continuing to develop innovative research areas between the experimental and the theoretical.

Several areas of reflection and cooperation have naturally emerged, centred on «innovation in extraction and recycling», «methodologies and theory of separation chemistry» and «optimising the life cycle of materials for energy». The first area requires experimental and theoretical development to optimise, better understand, and predict extraction and recycling principles. Some examples demonstrate this success. Firstly, the exceptional number of patents filed (around 20 between 2017 and 2020), which could not have developed to a world-class level (as shown by the citations in the international literature) without the close relationship between observation and theory. In practice, their emergence has been possible thanks to the tools used in the statistical physics of interfaces. Thus, the second area gathering competences around «Methodologies and theory of separation chemistry « continues to grow thanks to a large number of experimental protocols, such as the measurement and calculation of «lost» extraction molecules that are not active in the separation, or new separation methods without a classical extractant/surfactant. No less important are the recent advances in the field of soft X-ray microscopy and electron microscopy that allow the direct observation of supramolecular aggregates in solution with very high resolution, or the coupling of specific stages or cells with modern electron microscopes. No separation process can be achieved without knowledge of «material durability», i.e. materials that have to withstand extreme stresses and long use, not only in the life cycle of nuclear fuel, but also in that of all materials needed for alternative energy technologies. The life cycle of all implemented technologies must be studied and controlled as proposed in the «Optimising the life cycle of materials for energy» area. Solid/solid and solid/liquid interfaces are considered here since the physical and chemical properties of these materials (durability, robustness, containment and retention capacity...) depend on their synthesis, i.e. from the nature of the original form to the final material.

Supporting women and men: creativity, scientific and technical skills

To consider careful management of competences in order to achieve the objectives as originally set, but also with a view to preserving the forces present. Thus, the ICSM will remain one of the structures associated with the Transverse Directorate of Nanosciences at the CEA, with strong interactions with the organisations and institutions associated with the CNRS, the University of Montpellier, and the ENSCM.

Strengthening collaboration within the Chemistry Research Department.

Strong collaborations are already underway amongst the teams of the Chemistry Research Department through the various local, national and international research funding tools and should be sustained, or even strengthened, through the University of Montpellier.

Strengthening collaboration with industry.

At present, overall coherence is ensured by the common scientific culture, internationally through the European networks of excellence already initiated, through the interdisciplinary research programmes of the CNRS or by strengthening national and international industrial partnerships, or by the support of the promotion offices. From a methodical point of view, ANR, transverse CEA programmes, requests for co-financing from the region/CNRS/Industry will be submitted, in addition to the European projects, which constitute the daily work of fundamental research.

Investment in state-of-the-art equipment to ensure world-class research.

Because of the fields covered by the ICSM, specific equipment is required to support expertise in organic synthesis and its associated purification materials, synthesis and characterisation of inorganic and hybrid organic/inorganic materials, as well as original experimental equipment (multi-frequency sonochemical reactors, membrane filtration cells, flotation columns, Langmuir tank) and classical analyses or specific analyses (drop tensiometry, DLS, acoustic detection). The medium-heavy equipment used as part of the ICSM's scientific missions is partly assigned to the Institute's laboratories, in particular the analysis equipment (X-ray Diffusion/Diffraction, Environmental Scanning Electron Microscopes...), most of which are shared within the common analysis and characterisation platform (PAC) of the Chemistry Research Department. For characterisation by neutron scattering, the teams carry out their analyses on the large instruments of the Institut Laue-Langevin (ILL) and the Léon Brillouin Laboratory (LLB). The same is true for X-ray research with synchrotron beam time requested on the SOLEIL lines or at the

ESRF or the HZ in Berlin. As part of studies on the characterisation of materials under ion irradiation, experiments are carried out at JANNUS (Saclay) and GANIL (Caen).

Training future generations of scientists and promoting international mobility.

Training and support through research play a very important role within the Institute, through the association with INSTN and the SCB Doctoral School as well as through the work of several ICSM researchers and teacher-researchers. The ICSM welcomes around 15 doctoral students, and around 10 post-doctoral students and employees on fixed-term contracts each year. The ICSM is also very involved in the training of about 20 trainees per year with, in particular, the Franco-German exchange. Finally, the ICSM' researchers and teacher-researchers are involved in the Franco-Chinese Institute for Nuclear Energy (IFCEN). The first Specialised Open course «RECYCLING CHEMISTRY» in the field of separation chemistry and recycling, involves about 30 doctoral students every year.

Within the IEM

Maintaining a leading position in the development of membrane technologies.

In particular, membranes are considered to be dominant technologies in many industrialised countries today and for the future economy. The growth of markets associated with membranes is strong (7 to 10% per year on average over the last 10 years) and is driven by a variety of factors: scientific and technological advances, the emergence of new applications, increasingly stringent environmental regulations, major water-related challenges, and rapidly growing demand from developing countries.... Thus, from approximately €350 million in 1987, the market reached €17 billion in 2016 and €20 billion in 2018. In France, the Ministry of Industry has selected membranes as a «key technology», showing the strategic importance of this economic sector. The sector is therefore extremely dynamic and is particularly in need of innovative research and training tools. For the coming years, the unit's objective will be to develop high-level research projects concerning major scientific and/or technological challenges, mainly in the field of membranes, and which generally have important societal repercussions.

Anchoring research within the country in response to local and international socio-economic issues.

The IEM also intends to be fully involved in local scientific strategy, taking into account the major societal issues of the coming decades, whether in terms of food, water in the broad sense, or energy in particular. It will of course integrate the concepts of sustainability and durability into its scientific thinking. In particular, the principles of the circular economy will be considered in our projects, extending our thinking to economic and societal aspects. The city as an object of study, its development and its future, will also be components that we will take into account in our strategy, whether it be with regards to materials, for example, or at the level of water management. The unit also intends to develop its platforms to meet the scientific and technological requirements of external partners. It will also continue to strengthen its recovery activities. The perspectives already identified are set out below.

Sharing of complementary skills to serve the hydrogen sector.

Molecular hydrogen (H_2) is an essential raw material for many industrial processes. It has now become a key element of the energy transition, playing the role of a decarbonised electrical energy carrier with the fuel cell. The ability to produce, distribute, and use hydrogen with the smallest possible environmental footprint in terms of pollution and energy consumption is now both an industrial and societal challenge. The laboratory's project takes on this major challenge by pooling the complementary skills present in the laboratory to propose membrane systems covering all the different aspects of the hydrogen sector. The first step of our project is to ensure the most efficient production of H_2. Our objective is to develop new polymer membranes or membrane-electrode assemblies based on nanostructured or composite materials (such as ceramics, graphene and metals) for the photo or electrocatalytic decomposition of either water or bio-sourced compounds in the context of biomass valorisation into platform molecules. Our second research theme is the development of ceramic, hybrid or composite membranes for the separation, purification and detection of H_2. Materials for low-carbon energy storage and production through the H_2/O_2 fuel cell are also the focus of our project.

Supporting emerging areas of fundamental research: the development of 2D materials.

Two-dimensional (2D) nanomaterials, such as graphene, boron nitride (h-BN) or metal chalcogenides, represent interesting objects for membrane technologies and are an emerging research area at the IEM. Indeed, the potentially atomic thickness of the sheets could thus allow the creation of new membranes with tenfold permeance. However, this prospect is only possible if the porosity of the membranes can be controlled on nanometric or even atomic scales. Such monolayer membranes have been proposed theoretically and realised on a laboratory scale by several research groups but remain very difficult to implement. Alternatively, the 2D nanosheets can form nanolaminate membranes in which the porosity is generated by the space between successive sheets. These nanolaminate membranes are easier to implement and have already been tested in osmosis and reverse osmosis for the separation of nanopollutants or desalination. At this stage, research on membranes based on 2D materials must address two issues: (1) the study of the nanofluidic phenomena involved and (2) the development of controlled manufacturing methods that can be extrapolated to large scales for water purification, gas separation and osmotic power. The other major challenge lies in the preparation of nanosheets to enable the creation of membranes on planar or tubular substrates compatible with industrial technologies. 2D materials are remarkable because of the variety of their electronic, optical and catalytic properties, which could allow multifunctional membranes to be created (e.g. photosensitive, (photo-catalytic).

Developing processes for sustainable development and environmental protection.

A new process for the development of porous membranes, particularly adapted hydrophilic polymers, has been developed at the IEM. The formation of porosity results from the evolution of a spread and dried oil/water emulsion, prepared from a polymer solution and stabilised by nanoparticles (Pickering emulsion). A material cross-linking step integrated into the manufacturing process allows the membranes to be used in an aqueous medium for filtration. Nanoparticles are essential for maintaining porosity during the membrane development steps, and also provide new functions. Because of our diversified expertise in the synthesis of 2D inorganic materials (BN, Graphene, COFs, MOFs), inorganic nanoparticles (Si, Au, Ag, Fe_3O_4), block copolymers and colloid science, we are able to accurately develop a whole range of nanoparticles for evaluation. The development of filtration membranes based on water-soluble polymers is part of a sustainable development and environmental protection approach, as it reduces the use of organic solvents and the treatment of industrial effluents. Initial work at the IEM led to the preparation of membranes resistant to filtration conditions.

Investing in research to remove technological and industrial barriers.

The separating performance of membranes is mainly determined by the physico-chemical characteristics of the materials of which they are composed, as well as by their microstructure, which mainly involves porosity, tortuosity, pore size and distribution. Ceramic membranes are mechanically robust and are characterised by excellent chemical and thermal stability. They are therefore particularly useful for demanding applications, at high temperatures, in corrosive atmospheres and/or under high pressure. Thus, the use of ceramic membranes is increasingly being considered for industrial separation work. In contrast to organic membranes, ceramic membranes are relatively chemically inert and there are very few ways of controlling the alteration of their pore size. As the structure and chemical composition of the pore surface have a considerable influence on the performance of the membranes, it is of great interest to develop a simple and effective strategy to precisely modify/control the pore size and chemical composition of ceramic membranes. Atomic layer deposition (ALD) is a particularly suitable option for this type of application. It allows the growth of atomic-scale thin films on substrates with a very high aspect ratio. ALD allows the deposition of many materials such as oxides, non-oxides, or metals, in a wide temperature range. These depositions can be made on a wide variety of substrates, including ceramics or inert carbon materials, whose surfaces can thus be functionalised and whose microstructure can be adjusted. The goal is to develop an innovative method for preparing membranes with optimised separation performance, starting with simple commercial porous membranes with an understood microstructure. Membrane manufacturers, integrated system designers or users are therefore expected, at local, national or international level, to gain industrial benefits.

Research geared towards the UN sustainable development goals.

Research project in the field of water treatment is linked to the UN SDGs and will be developed within the nexus: Water, Energy, Environment, and Food. This could consist of producing treated wastewater suitable for a second life by (1) making the level of sanitation of the water produced reliable by developing effective steric hindrance with low clogging, but also (2) ultrafiltration-nanofiltration, ultrafiltration-reverse osmosis, or relevant combinations (advanced oxidation-membrane or enzymatic reactions-membrane) for direct recycling where it is

necessary to develop technological building blocks for the production of water with physico-chemical qualities close to those required for drinking water thanks to multi-barrier membranes. Thus, the global trends in technological innovation are to improve the reliability, performance, flexibility and robustness of existing technologies at competitive cost and with improved energy efficiency. The Water-Energy-Environment-Food nexus involves adapting treatment for different uses, while imagining positive energy channels by anticipating health and environmental risks (emerging pollutants and salt management) for indirect (irrigation, groundwater replenishment) or direct recycling.

Development of activities with and for southern countries.

The unit will continue to invest in applied projects that demonstrate the value of membrane techniques for water purification. An example of what we want to support is (1) the «Investissement d'Avenir» (investing in the future) project entitled «Demonstrators of ecological and energy transition», led by the company MASCARA, which demonstrates the industrial and commercial feasibility of seawater desalination processes by solar osmosis, (2) the projects currently being set up with the UNESCO SIMEV Chair in Africa.

Creation of Membrane Technology Platforms open to private partners.

The unit has a set of pilot equipment for the implementation and operational characterisation of membranes on both gas and liquid separation issues. The goal is to rely on the most durable industrial partnerships with industrial manufacturers or users of membranes to develop the internal structure for platforms open to public and private research. It seeks to implement and/or test technological solutions at the membrane or membrane process level.

NOTES

The White paper of the Chemistry Research Department of the University of Montpellier is the result of the commitment of students, research support staff, researchers, teacher-researchers and management committees to support the successful construction of the I-SITE initiative, Montpellier University of Excellence, now fully integrated within the University of Montpellier.

To celebrate those 5 years of efforts undertook by the entire Chemistry community into the I-SITE, this document presents the Chemistry Research Department in its entirety in order to provide a better understanding of its activities, infrastructures and contributions to society.

It is a testimony to the determination of the Chemistry Department to support the positioning of the University of Montpellier among the best universities.

This white paper also aims to present the ambitions, ideas and resources required by our department to build the University of tomorrow in order to better respond to the major scientific, technological, economic, environmental and societal challenges of the decades to come.