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Chemistry in France: A Hotbed for New Schools of Thought**

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(Photo: Francis Vernhet)

How is chemistry standing in the land of Lavoisier, while we're celebrating the 100th anniversary of the Nobel Prize in Chemistry to Paul Sabatier and Victor Grignard, within a rapidly changing higher education and research landscape? France has a long-standing tradition of research and innovation in chemistry, and its chemical industry (ranked fifth in the world) is still a strong pillar of French economic development. More than 3300 chemical companies directly employ 200000 people (inducing 600000 indirect jobs). Most of these are small or medium companies, together with some large industrial groups such as Total, Arkema, Rhodia, Michelin, and Air Liquide. This strong industrial activity has generated, in the first part of the 20th century, the foundation of several chemistry and chemical engineering graduate schools all over the country, attracting very good students educated as chemical engineers to a masters level. On the academic side, some 5300 researchers and 2700 technical staff work in chemistry laboratories and teams, located in the most important French academic cities. All of the main research topics are addressed in the core of chemical science and in all of its interfaces with physics (such as materials science, nanosciences, soft matter, spectroscopies), life sciences (medicinal chemistry, bioinspired chemistry, structural biology), and engineering (optoelectronic devices, energy storage, metallurgy).

A distinctive feature of the French research system is the existence of a nationwide research-performing organization, the "Centre National de la Recherche Scientifique" (CNRS), which employs full-time, and long-term, research fellows as well as technical staff (some 25000 people overall). It is multidisciplinary (http://www.cnrs.fr) and one out of its ten departments is fully devoted to performing research in chemistry. CNRS employees are mostly located in university premises. The CNRS–university partnership is established through joint research laboratories ("Unités Mixtes de Recherches", UMR), in which professors and CNRS research fellows work together very efficiently. Young CNRS fellows may move to a professorship position in a university, and this corresponds to a career acceleration. It is quite frequent in some disciplines such as mathematics, but less so in other fields of research where there are fewer university positions available, and because teaching duties in universities can be quite high.

France has a long-standing tradition of research and innovation in chemistry

This type of organization has its advantages and drawbacks. The presence of a large number of permanent positions for researchers and staff in a given university department or laboratory is considered as a real advantage. It allows a continuing long-term research effort, something that is important in chemistry where high-level research often requires specific experimental skills that take a long time to acquire. It has also allowed to establish new schools of thought, such as "soft chemistry" initiated by Jean Rouxel and further developed by Jacques Livage and others. The inventiveness of Gérard Férey, a pioneer in the synthesis of MOFs with very large pores, and Clément Sanchez in the field of multiscale bioinspired functional materials are examples of recent new and very promising schools of thought in the chemistry of materials. The development of ultramicroelectrodes by Christian Amatore is another example of an exciting new field at a crossroad between electrochemistry and modern analytical chemistry.

Supramolecular chemistry is a prototypical school of thought. It has emerged in France at the University of Strasbourg with Jean-Marie Lehn, and has rapidly grown (for example, the laboratories of Jean-Pierre Sauvage and Mir Wais Hosseini). The Institut de Science et d'Ingénierie Supramoléculaires (ISIS) laboratory, led in the last few years by Thomas Ebbesen, is now a hotspot of multidisciplinary world-class science, attracting young researchers such as Paolo Samorì, Luisa De Cola, or Daniel Riveline. Many bright former students and postdocs have obtained university positions at many locations, and Lehn's

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school of thought is now disseminated all over the world.

A genuine advantage of the French system is that it allows multidisciplinary teams and laboratories to be built up, for instance mixing chemists with physicists, engineers, and biologists. Among others, we may cite the Institut Jean Lamour (metallurgy and materials center) in Nancy, headed by Jean-Marie Dubois, the physical chemistry and biopharmaceutical institute created by Patrick Couvreur at Université Paris-Sud, and the (nano)materials chemistry and physics institute in Strasbourg, headed by Marc Drillon.

The added value of a nationwide research organization lies in the possibility of building up and managing scientific and technological networks throughout the country. Such networks exist in areas including theoretical chemistry, fuel cells, magnetic materials, and ultrahigh-field NMR spectroscopy. One of the most active and promising networks is headed by Jean-Marie Tarascon on the hot topic of electrochemical energy storage. Teams and laboratories located in Amiens, Bordeaux, Nantes, Toulouse, Montpellier, Pau, Orléans, and Mulhouse work together and bring their expertise in chemistry, physics, and engineering in a very effective manner with the aim of creating some of the most powerful batteries that are badly needed to address the world energy problem. For this kind of challenge, the role of the CNRS is to suggest that cooperation between some of the best groups is sometimes more efficient than mere competition. Whenever it works that way, the CNRS is there to manage the networks.

The CNRS also favors joint research projects between French groups and industry, and also with foreign universities. Long-term collaborations may take the form of joint research laboratories such as the "laboratory of the future" in Bordeaux, where university and CNRS fellows work together with employees from the company Rhodia. Such a joint laboratory can either be located in university or industry premises, like the Saint Gobain–CNRS laboratory in Cavaillon. In all cases, the research projects are focused on mixed fundamental and applied topics addressed by a mixture of academic and industrial researchers. The concept of the joint international laboratory is best illustrated by the success story of Guy Bertrand, who heads a research group dedicated to the synthesis of stable carbenes and other supposedly unstable reagents at the University of California, San Diego (formerly at the University of California, Riverside). In this group, five permanent CNRS fellows and several French postdocs enjoy the advantages of both the US and the French systems! Among the several tens of such joint laboratories, we have recently launched a mixed laboratory dedicated to green chemistry research with Rhodia in Shanghai. Overall, the international and/or industrial networking managed by the CNRS allows some of the brightest young French scientists to benefit from a high-level experience abroad. After a period overseas, the best young scientists often apply for a CNRS or university position (as "chargé de recherche" or "maître de conference", which corresponds to an assistant professorship). These positions in France also attract excellent scientists from abroad, which correspond to about 30% of the newly recruited CNRS researchers each year.

France has recognized the importance of building up world-class research universities

A strong research activity in chemistry is present in the "grandes écoles" (engineering graduate schools that select the best students in science through high-level nationwide entrance examinations) and specifically in the chemistry and chemical engineering graduate schools mentioned above ("grandes écoles de chimie"). This enables the education of chemical engineers by contact with high-level research groups. Examples of this system are the research groups of Janine Cossy and Ludwik Leibler at École Supérieure de Physique et Chimie de Paris (ESPCI-ParisTech), Gérard Jaouen and Carlo Adamo at the École Nationale Supérieure de Chimie de Paris (Chimie-ParisTech), and Samir Zard at the École Polytechnique.

Every organization has its drawbacks, and it has often been suggested that the French research organization was perhaps not flexible enough (climbing up the career ladder is slow, lack of turnovers from academic to industry positions, and administrative barriers discourage the creation a small business). However, it offers considerable freedom of research with the possibility of undertaking risky and long-term projects. To mention only one (but striking) example, Bruno Chaudret moved from his studies of dihydrogen ruthenium complexes, for which he was widely recognized, to the synthesis of nanoparticles based on organometallic precursors to become one of the world leader in this new field. The impression I have is that nowadays more and more young French chemists are inspired by such examples.

The French research and higher education landscape is subject to a rather profound change these days. Like many other countries, France has recognized the importance of building up world-class research universities. Work is in progress and we may expect in the coming years to end up with a certain number of new multidisciplinary universities in France, some having the scientific potential to be in the competition with the best in the world. The CNRS is playing its part in this evolution, with the aim of reinforcing its partnership with universities, while keeping up in the development of strong and efficient research networks in France and abroad. Above all, it is the attractiveness of science for young people and the international visibility of French science (including chemistry of course!), that will have to benefit from such an evolution.

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