NJC
Opinion

Chimie douce: wide perspectives for molecular chemistry. A challenge for chemists: control of the organisation of matter

Robert J. P. Corriu

Laboratoire de Chimie Moléculaire et Organisation du Solide, Université Montpellier II, 2, Place E. Bataillon, CC 007, 34095 Montpellier cedex 5, France

Received (in Montpellier, France) 20th November 2000, Accepted 30th November 2000
First published as an Advance Article on the web 19th December 2000

Inorganic polycondensation is opening materials science to molecular chemistry because of its compatibility with any molecule or macromolecule.

Our attitude towards new ideas or new concepts is highly dependent on the background information that we possess. Our own culture is the main parameter that governs our attitude when confronted with a novelty. The concept of '*chimie douce*' is a breakdown in materials synthesis and Jacques Livage, who is one of its fathers, in his Opinion gives the view of a solid state chemist. Faced with the same concept, my life as a molecular synthetic chemist causes me to have a viewpoint complementary to his. I consider that *chimie douce*, especially the sol–gel-type polycondensation, opens very wide perspectives for synthetic chemistry that will allow the solids obtained to combine the physical and chemical properties of their precursors.

As a first approximation, we can consider that the synthesis of solids uses one of two methodologies. The first is the classical thermal access to materials that leads to stable (crystals) or metastable (glasses) solids. In contrast, using inorganic polycondensation molecular chemistry provides the means to enter into the domain of solid state chemistry, which is the door to materials science. Up to now, inorganic or organic materials were solids in which isolated molecules were packed in a crystal lattice; the packing determined the physical properties. Since the inorganic matrices formed by the inorganic polycondensation process exhibit complete compatibility with any molecule or macromolecule, new possibilities for hybrid materials are created. The solids obtained in this way are kinetically controlled and we are thus faced with a completely different situation for the preparation of materials, as the solids obtained can lie far from equilibrium. This chemistry, called hybrid materials chemistry, started about 10 years ago. At the present time, different types of hybrid materials have been prepared, mainly in silica.

Nanocomposites are polyphasic materials in which a physical, chemical, or biological entity is embedded in an oxide matrix; these are the most convenient for producing devices for materials science. The entity possessing the desired property is included in a matrix in a low-temperature process and it is possible to produce a variety of suitable forms: films, fibres and matrices.

A new chemistry is afforded by nanostructured materials and mesoporous materials, two other types of hybrids that behave differently. In *nanostructured materials*, the organic species is bound to the silica matrix by at least two Si–C bonds. The inorganic polycondensation process allows any kind of device to be obtained because the viscous sol formed can be spun into fibres, used as a matrix or coated as a film onto a surface, before solidification takes place. The thermal stability of these materials extends beyond 400 °C and the physical or biological properties are protected in the matrix. It also appears that organic moieties are incorporated without change. However, synthetic studies of these materials are just beginning since there is no limit on the choice of species that can be incorporated. Any organic, organometallic or polymeric molecule or transition metal complex, *etc.* can be chemically attached to the matrix without changing its desired physical properties (optical, electrochemical, photoluminescent, magnetic, *etc.*). Moreover, the possibility of short- and sometimes long-range order of the units bound to the solid leads to very specific chemical properties not observed in solution and which should lead to interesting materials.

Mesoporous materials, discovered in 1992, are obtained by an inorganic polycondensation process performed using a micellar-type medium as a template. This route is highly promising since it allows both the size of the pores and the chemical functionalities included to be controlled: in other words we have both chemical and textural control. Transition metals have already been bound within the pores of mesoporous materials for catalytic applications. Selected chemical functionalities will permit the inclusion of any physical species in the channel: metallic or semiconducting particles, photoluminescent, electroluminescent or photochemically active compounds or particles, *etc.*

Recently, another possibility was revealed by the binding of hybrid moieties onto the pore walls. The control of this new synthetic methodology is very important since, in the near future, it will be possible to include one type of species in the framework and different ones in the channels. The interactions between their respective properties will be of interest. Of course, all these prospects require the development of the chemistry that will allow control of the various parameters involved: size and functionality of pores, nature of spacers, inclusion in the framework and in the channels, as well as the use of matrices exhibiting specific physical and chemical properties, such as TiO_2, V_2O_5, SiO_2 or ZrO_2.

Thanks to the concepts introduced by *chimie douce* and their development as exemplified by the inorganic polycondensation process, chemists are discovering a world in which control of the organisation of the physical and chemical properties of matter is in perspective. A new chapter of very fruitful chemistry leading to new physical and chemical properties is being written.

 DOI: 10.1039/b009662h