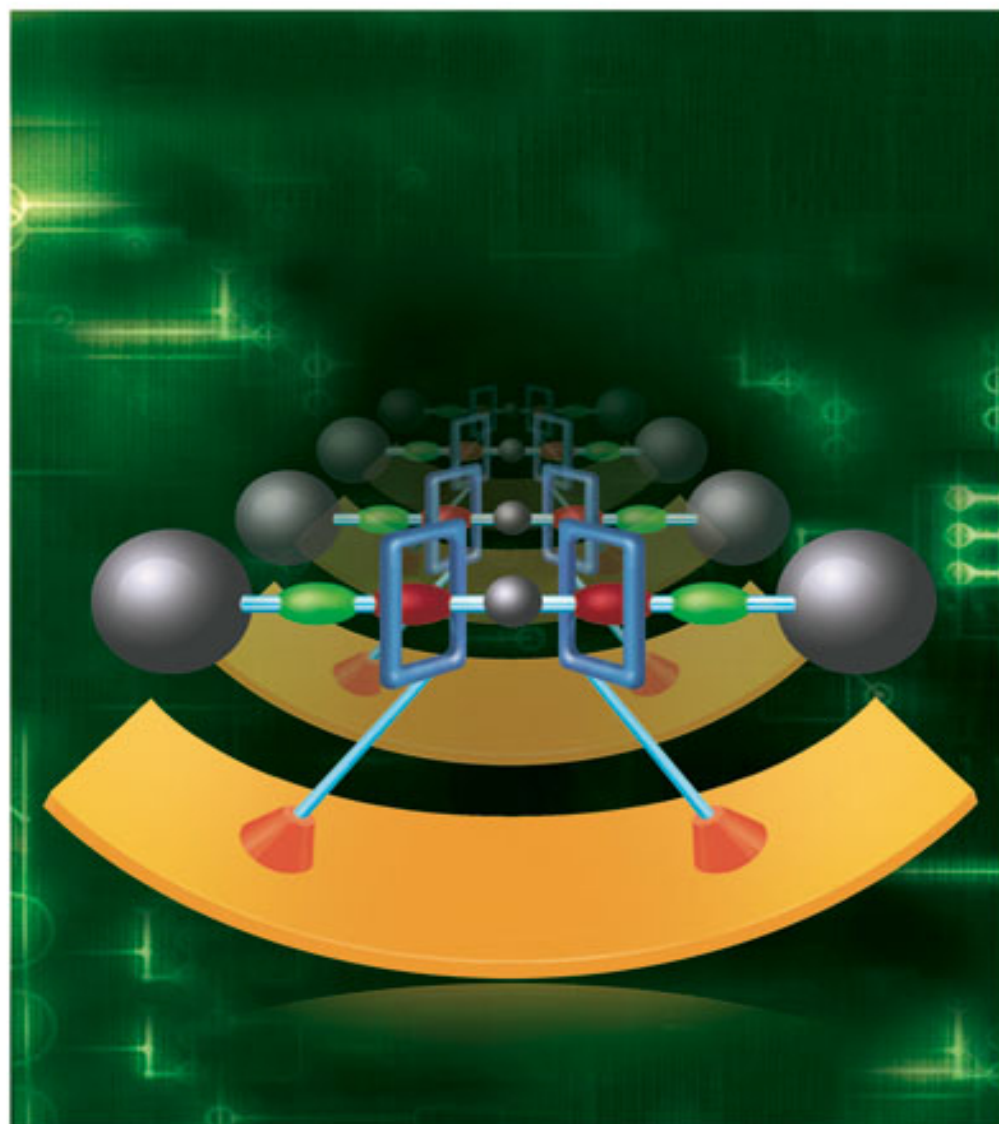


Edited by Jean-Pierre Sauvage
and Pierre Gaspard

 WILEY-VCH

From Non-Covalent Assemblies to Molecular Machines



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From Non-Covalent Assemblies to Molecular Machines



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Preface

It was a great honor and a real pleasure to chair the 21st Solvay Conference on Chemistry. The prestigious Solvay Conferences on Physics or on Chemistry are all known by the various scientific communities as major events, with a historical impact that is universally recognized. It is obvious to all of us that these conferences had a strong influence on the way physics and chemistry evolved during the course of the past hundred years or so. The spirit and the organization of the conference on chemistry “From Monovalent Assemblies to Molecular Machines” were in accordance with those of the previous conferences. The format was indeed unique: no classical lectures, a pre-eminence of questions and comments and, as a testimony for the widest possible community and for the future scientists interested in the fields discussed during the event, detailed proceedings gathering the various general lectures (“reports”), short presentations (“prepared comments”) and, last but not least, discussions on the prepared comments.

The theme of the Conference was relatively wide, since, *a priori*, noncovalent assemblies have almost no relationship with controlled dynamic systems (molecular machines). However, at the same time it was relatively focused since, historically, these two fields are tightly linked. The first area is an important subfield of supramolecular chemistry, the development of which has been spectacular during the course of the past 30 years or so. In the particular context of the Conference, transition metals and hydrogen bonds played a special role. The second field, related to molecular motion, is more recent and, to a large extent, has derived from the flourishing field of interlocking compounds (“catenanes and rotaxanes”), the synthesis of which has undergone a spectacular revival during the past 20 years or so. Of course, the creation of interlocking ring structures relies on the ability of molecular chemists to assemble

precisely defined multicomponent edifices before making the desired catenanes or analogous species, which was the first topic of the conference.

Functional interlocking compounds—the constitutive elements of which are held together only by “mechanical bonds” rather than covalent bonds—are conceptually particularly well adapted to the study of large-amplitude molecular movements, as the various fragments of catenanes and rotaxanes can move with almost no constraints. A ring can spin around the axle on which it has been threaded, and it can also glide over large distance along the same axis.

Triggering and studying molecular motion is not restricted to interlocking systems. In this context, noninterlocking compounds have also turned out to be of high interest, especially as far as rotary motions are concerned. For both classes of molecules, ingenious chemists have been able to set given fragments of the molecule in motion by using various types of stimulus (light pulse, electrochemical signal, heat, modification of the solvent, etc.). The relation between molecular biology and the numerous motor proteins found in Nature is obvious, as is the connection to physics and Brownian molecular machines, which are of utmost importance in biology.

The use of complex molecular systems, which are able to behave as switches or to display novel properties in relation to molecular logic or artificial photosynthesis, seems to be promising and, even if these research topics are not strictly speaking part of the molecular machine field, they were sufficiently close from a conceptual viewpoint to form part of the themes discussed during the Conference. The high level of interaction between the scientists classified as belonging to a given subfield was a demonstration that it is indeed important to allow various communities to meet and work together.

Finally, a critical point is to know whether applications might be expected in the near future or, at least, to consider possibilities related to practical devices. Some of us have already started to envision important applications, and also to realize highly promising devices from a practical standpoint. It was important to compare the points of view of these investigators with those of more basic-science-oriented researchers. Single-molecular devices, as well as ordered or condensed states of matter consisting of the various molecular systems discussed during the Conference, are certainly to be considered with respect to various applications. Consequently, a special session was devoted to single molecules and their potential, mostly in relation to information storage and processing.

All of the participants at the 21st Solvay Conference on Chemistry are extremely grateful to the Solvay family for their very generous support. The tradition started by this family so long ago is highly beneficial to the scientific community in general, as the Conferences have a scientific impact that goes much beyond the meeting itself. In addition to the generous sponsors whose support made the Conference possible, I would also like to thank all of the participants for their great contributions, as well as the younger colleagues who took care of all the practical aspects of the conference, who gathered the various written reports and comments, and who transcribed the oral presentations, comments, questions and answers. Without their important contribution, the preparation of this book would never have been possible.

Jean-Pierre Sauvage

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Description

21st Solvay Conference on Chemistry

Hotel Metropole (Brussels), 28 November-1 December 2007

“From Noncovalent Assemblies to Molecular Machines”

Chair: Professor Jean-Pierre Sauvage

The 21st Solvay Conference on Chemistry took place in Brussels between 28 November and 1st December 2007, according to the tradition initiated by Lorentz at the 1st Solvay Conference on Physics in 1911 (“Premier Conseil de Physique Solvay”). The Conference was followed on 2nd December by a public event, during which J.-M. Lehn delivered a public lecture entitled “De la Matière à la Vie: la Chimie? La Chimie!” and a panel of scientists (B. Feringa, V. Heitz, J.-P. Launay, J.-M. Lehn, D. Leigh, A. Moore, J.-P. Sauvage and F. Stoddart) answered questions from the audience.

The organization of the 21st Solvay Conference has been made possible thanks to the generous support of the Solvay Family, the Solvay Company, the Belgian National Lottery, the “Université Libre de Bruxelles”, the “Vrije Universiteit Brussel”, the “Communauté française de Belgique”, the David and Alice Van Buuren Foundation, the Wiener Anspach Foundation and the Hotel Metropole.

Opening Session

Opening address by Marc Henneaux

Dear colleagues, dear friends,

In the name of the International Solvay Institutes, it is my great pleasure to welcome all of you to the 21st Solvay Conference on Chemistry. This is the first Solvay Conference on Chemistry to be held in the 21st century.

Since I have only a few minutes, I will be brief. I thought it would be of interest to give you some historical background on the Solvay Conferences on Chemistry.

The history of the International Solvay Institutes started in 1911, with the first Solvay Conference on Physics. I am sure that you have all seen the famous photograph where Marie Curie, Lorentz, Poincaré, the young Einstein and other celebrities surround Ernest Solvay.

In view of the success of the 1911 conference, Ernest Solvay created the Institute of Physics in 1912 and the Institute of Chemistry in 1913, which have now merged into the “International Institutes for Physics and Chemistry, founded by Ernest Solvay”, or the “International Solvay Institutes” for short. One central mission of the Solvay Institutes is periodically to organize the famous Solvay Conferences. The list of all the conferences that have taken place in chemistry is as follows:

1. 1922 Cinq Questions d'Actualité

Chair : William Pope (Cambridge)

2. 1925 « Structure et Activité Chimique »

Chair : William Pope (Cambridge)

3. 1928 « Questions d'Actualité »
Chair : William Pope (Cambridge)
4. 1931 « Constitution et Configuration des Molécules Organiques »
Chair : William Pope (Cambridge)
5. 1934 « L'Oxygène, ses réactions chimiques et biologiques »
Chair : William Pope (Cambridge)
6. 1937 « Les Vitamines et les Hormones »
Chair : Fred Swarts (Gand)
7. 1947 « Les Isotopes »
Chair : Paul Karrer (Zurich)
8. 1950 « Le Mécanisme de l'Oxydation »
Chair : Paul Karrer (Zurich)
9. 1953 « Les Protéines »
Chair : Paul Karrer (Zurich)
10. 1956 « Quelques Problèmes de Chimie Minérale »
Chair : Paul Karrer (Zurich)
11. 1959 « Les Nucléoprotéines »
Chair : A.R. Ubbelohde (London)
12. 1962 « Transfert d'Energie dans les Gaz »
Chair : A.R. Ubbelohde (London)
13. 1965 « Reactivity of the Photoexcited Organic Molecule »
Chair : A.R. Ubbelohde (London)
14. 1969 « Phase Transitions »
Chair : A.R. Ubbelohde (London)
15. 1970 « Electrostatic Interactions and Structure of Water »
Chair : A.R. Ubbelohde (London)
16. 1976 « Molecular Movements and Chemical Reactivity as conditioned by Membranes, Enzymes and other Molecules »
Chair : A.R. Ubbelohde (London)

17. 1980 « Aspects of Chemical Evolution »

Chair : A.R. Ubbelohde (London)

18. 1983 « Design and Synthesis of Organic Molecules Based on Molecular Recognition »

Chairs : Ephraim Katchalski (Rehovot) and Vladimir Prelog (Zurich)

19. 1987 « Surface Science »

Chair : Frederik W. de Wette (Austin)

20. 1995 « Chemical Reactions and their Control on the Femtosecond Time Scale »

Chair : Pierre Gaspard (Brussels)

A striking feature of the subjects of the conferences is their diversity, ranging from physics to biology.

The previous conference on chemistry took place in 1995. With the organization of the 21st Conference, 12 years after the 20th one, we are happy, at the Solvay Institutes, to revive a tradition that has been dormant since then. I would like to express our deepest thanks to the Solvay Scientific Committee for Chemistry, represented here by its Professors Stuart Rice (chair), Graham Fleming, Henk Lekkerkerker, Jean-Marie Lehn and Albert Goldbeter (secretary), who chose the subject of the conference, and to Professor Jean-Pierre Sauvage from the University of Strasbourg who accepted to chair it.

In preparing my speech, I was informed by Professor Franklin Lambert (VUB) that there are, in fact, many historical links between the University of Brussels and the Solvay Institutes on the one hand, and the University of Strasbourg on the other hand. These links go back to the early days of the Institutes, after the First World War. The physicist Pierre Weiss, known for his important work on magnetism, was a cornerstone of this cooperation. It is interesting to note that Pierre Weiss, as early as in 1920, pushed for an exchange program between professors and lecturers of both Brussels and Strasbourg Universities, and