Supramolecular Chemistry

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Supramolecular Chemistry

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Springer Science+Business Media, B.V.

Proceedings of the II NATO Science Forum on
Supramolecular Chemistry
Taormina (Sicily), Italy
December 15–18, 1991

Library of Congress Cataloging-in-Publication Data

Supramolecular chemistry / V. Balzani and L. De Cola.
p. cm. -- (NATO ASI series. Series C, Mathematical and
physical sciences ; no. 371)

Includes indexes

ISBN 978-94-010-5099-9 ISBN 978-94-011-2492-8 (eBook)

DOI 10.1007/978-94-011-2492-8

1. Macromolecules--Congresses. I. Balzani, Vincenzo, 1926-
II. De Cola, L. (Luisa) III. Series.

QD380.S86 1992

547.7--dc20

92-5813

ISBN 978-94-010-5099-9

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Originally published by Kluwer Academic Publishers in 1992

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FOREWORD

The first NATO Science Forum was held in Biarritz in September 1990. This Taormina Conference is the second in a series that we wish to be a long one and I believe that it has equalled the success of its predecessor. In setting up these meetings the NATO Science Committee wanted to gather leading experts to review fields of strong present interest. It was intended that presentations and discussions should pay special attention to potential developments. This "forward look" is indeed precious to us in mapping out the evolution of our Science Programme but more importantly, it is an essential part of the progress of Science. I believe that NATO, being able to bring together eminent scientists from both sides of the Atlantic, is in a privileged position to provide this service to our Scientific Community.

It was only proper that Chemistry should be one of the first areas to be targeted: a central science with many rich borders touching on other disciplines, it deserved the full attention of our Committee. In its vast domain, among many possible topics, the present one was carefully selected and its choice resulted from an extensive consultation of many leading chemists. The large fraction of replies which pointed to Supramolecular Chemistry left us with little doubt about the timeliness of a Forum in this area and the strong interest attached to it.

In fact the field seemed to us important enough to warrant a particular effort from our side. This is why we decided at the same time to support it through a NATO Special Programme. Through this mechanism we shall focus for the next five years part of our activities (Advanced Study Institutes, Advanced Research Workshops, Collaborative Research Grants, etc.) on this highly promising area in order to catalyze the development of international collaborations. We hope that this development will extend beyond the member countries of NATO and will particularly actively involve the scientists of Central and Eastern Europe. I am happy to note that several of our "non-NATO" colleagues were already present in Taormina.

The NATO Science Committee is deeply indebted to all those who assisted us in getting this new initiative started. They are too numerous to be all cited here but special thanks go to Professor Balzani who assumed the heavy burden of organizing this very successful Forum. As for the future I hope that the direction indicated by the Biarritz and Taormina meetings will be followed with the continued support of the NATO Science Programme.

Jacques Ducuing
Chairman of the NATO Science Committee

FOREWORD

Supramolecular chemistry, the chemistry beyond the molecule, is a highly interdisciplinary field, at the meeting point of chemistry with biology and physics.

It extends into organic chemistry and the synthetic procedures for receptor construction, into coordination chemistry and metal ion-ligand complexes, into physical chemistry and the experimental and theoretical studies of interactions, as well as into biochemistry and the biological processes that all start with substrate binding and recognition. The resulting cross-fertilization opens wide horizons that represent a challenge and a stimulus to the creative imagination of the chemist.

Based on the chemical, physical, and biological features of recognition, catalysis and transport processes, novel lines of investigation have developed, concerned with the design of supramolecular photonic, electronic and ionic devices as well as of systems displaying higher forms of molecular and supramolecular behavior such as self-organization, regulation, cooperativity, communication, and replication.

The development of supramolecular chemistry involves a more and more complete control over supermolecules, molecular assemblies and materials. It rests on the elaboration of strategies towards properties and functions rather than towards structures, the goal being to express a desired property in a molecule or a material, whatever its nature.

The attractive power of supramolecular chemistry expresses itself in the many researchers from different fields who recognize themselves in its projects and are shaping its present and its future. Its coming of age is attested by the numerous highly imaginative and active groups that join it, by the many books that provide overviews and of course by the illuminating encounters that report advances and seed new projects.

It is always a great enjoyment to see how much each meeting, each symposium adds to the picture and enriches the perspectives.

The initiation of a NATO Special Program on "Supramolecular Chemistry" is most welcome; it should provide further impetus and facilitate the exchange of ideas and researchers. The first activity held within this scheme was the present symposium, that has brought together many of the most active actors in the field. Judging from the presentations made, it has indeed achieved the goals of imagination and diversity, the keys to creative research.

Both the funding agency and the organizers are to be thanked most warmly for furthering our common good, supramolecular chemistry!

Jean-Marie LEHN

PREFACE

Chemistry is the most central of the scientific disciplines. Any possible link between biology and physics is through chemistry. Material science, chemical engineering, earth sciences, ecology, and related areas are largely based on chemistry. In the September 13th, 1991 issue of *Science* (p. 1212) there is this beautiful description of chemistry: *Like a species that has moved into open niches, evolved and diversified, chemistry can no longer be seen as a discrete scientific field; its methods, concepts, and practitioners are penetrating virtually every nook and cranny of Science and Technology.* And in an Italian scientific magazine (*Sapere*, August 1991, p. 34) it was pointed out that *chemistry can now be regarded as a trans-disciplinary science, as is mathematics: a science that provides an essential means and a fundamental "language" to fully understand other scientific disciplines.* Everybody knows that chemical research is a fundamental factor for the progress of humanity. The most important global problems (food, human health, energy, environment) cannot be solved without chemistry. Without chemistry there would be no hope in filling the gap regarding the quality of life between developed and developing countries.

Unfortunately, chemical research is largely underfunded. Two examples taken from our own country, but certainly representative of a general situation, will suffice to demonstrate this issue: (i) the sum spent to buy twelve Harrier vertical-landing bombers for the Italian Navy is as much as four times the sum spent in 1991 by all the Italian public research agencies (MURST, CNR, ENEA, ISS, etc.) to finance chemical research; (ii) the subdivision of the 1991 budget for scientific research in Italy was as follows: space 23%, physics 18%, chemistry 4%. These two examples, of course, show where changes should be made in the allocation of financial resources.

In the present situation, the decisions taken by NATO to reduce by 80% its nuclear arsenal in Europe and to launch a new Special Programme in the field of Chemistry are most welcomed. These two decisions were certainly unrelated and concern, in fact, very different budgetary and political levels. We like to believe however, that the coincidence in time and location between those two events*, albeit casual,

*The decision to reduce the nuclear arsenal was taken at the Defense Ministers meeting of NATO Countries at Taormina (Sicily) on October 17, 1991; the NATO Special Science Programme on Supramolecular Chemistry was launched by the II NATO Science Forum on December 15-18, 1991, in the same town.

is of the utmost significance since it offers an opportunity for meditation to scientists and politicians.

Chemical research can certainly be a fundamental factor for the progress of humanity, but it must be driven in the right direction. Past experience shows that scientific and technological progress takes place mainly at the cross-roads of different disciplines. Therefore, as a first action we need to demolish all those artificial barriers which have been created to subdivide chemistry into specialized subdisciplines like organic chemistry, inorganic chemistry, physical chemistry, and so on. Supramolecular Chemistry is an appropriate vehicle for this reunification.

But what is "Supramolecular Chemistry"? As for any other interdisciplinary field of science, a general definition would necessarily be arbitrary. Different meanings can in fact be attributed to Supramolecular Chemistry and the II NATO Science Forum has shown many facets of this interdisciplinary field. The importance of this meeting can be measured, in fact, not only by the number of represented countries (16), but especially by the number of represented disciplines (more than 20).

The conceptual feature that distinguishes a supramolecular from a molecular species is not its size, but the possibility to split the species into individual molecular subunits (components) capable, as they are or with minor modification, of an individual existence. Such a definition is clear-cut in several cases, i.e. when the components are molecules held together by intermolecular forces as in the case of host-guest systems. In other cases (e.g., for covalently linked components) the definition is more subjective. The main characteristic of supramolecular species is certainly the possibility to construct them by combining molecular building blocks in the same way as molecules are obtained by the combination of atoms. A suitable choice of the building blocks and their appropriate location in the supramolecular array are, of course, the key factors in obtaining new materials capable of performing new functions.

In the context of the imaginative and creative area of Supramolecular Chemistry, the II NATO Science Forum held at Taormina in December 1991 offered the opportunity for very interesting reports and discussions on important challenges: the design, synthesis, and characterization of new building blocks and new assemblies with desired structures and properties for (i) molecular recognition, self-organization, and self-replication, (ii) selective catalysis and reactivity, (iii) energy and electron transfer processes related to the elaboration of signals, information storage, and solar energy conversion, and (iv) encapsulation of radicals and unstable molecules. These and other related topics are extremely important both from a fundamental and an

applicative viewpoint. But we should not forget another appealing aspect of Supramolecular Chemistry: namely, the intrinsic beauty of most supramolecular species, the aesthetic value of their architectures; some supramolecular species are not only chemical, but also artistic masterpieces.

The main factor for the success of the Forum was, of course, the high scientific level of the presented lectures, which have been collected in this volume.[#] Another important factor for the success was the enthusiastic involvement of participants and observers during the long time periods dedicated to formal and informal discussions.

We would like to thank Prof. Jacques Ducuing and Dr. Alain Jubier of the NATO Scientific Affairs Division for their constant help and encouragement. Financial support was mainly offered by NATO, with additional contributions from Consiglio Nazionale delle Ricerche, ENEA, Bracco Industrie Chimiche, Regione Sicilia, Comune di Messina.

We would also like to thank the members of our research group, in particular Massimo Guardigli and Luca Prodi, for their assistance in organizing the meeting. A special thank goes to the staff of the Jolly Hotel Diodoro of Taormina who offered us not only outstanding facilities for the scientific sessions, but also a friendly and peaceful atmosphere in a beautiful surrounding (including fireworks from the Etna volcano!).

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[#]Besides 27 papers presented at the Forum, this book also contains two papers that could not be delivered due to the last minute problems that prevented the participation of two expected lecturers.

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