Angewandte Chemie 50 Years International Edition

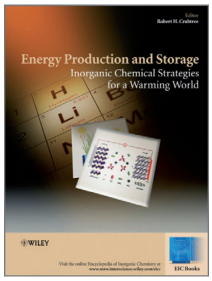
Energy Production and Storage

Probably the most important crucial issues that our civilization is now facing are problems related to energy resources. At present, total world energy consumption is about 13 TW. About 85% of this energy demand is supplied by fossil fuels, which are non-renewable energy sources. World energy consumption is certain to increase, and is estimated to approach 27 TW within a few decades. Such a huge energy demand cannot be covered by oil, natural gas, or coal without causing enormous damage to the earth's equilibrium. This damage is already apparent in the global warming that we are experiencing, undoubtedly due to the large and unsustainable CO_2 emissions caused by extensive use of fossil fuels for energy production. To make this picture worse, "peak oil" is expected to be reached in the next few years, even according to the most optimistic estimates. When that is reached, oil production will not, of course, be over, but that will be (or perhaps already is) the end of the era of cheap oil. Probably the most immediate action needed is to reduce the use of the still available fossil fuels, by optimizing processes and avoiding extra and unnecessary consumption (only people who disregard the second law of thermodynamics would believe that energy consumption could increase indefinitely in the world, if it is considered as a closed thermodynamic system). But in addition we absolutely need to develop new methods for making greater use of renewable energy sources. Besides economic considerations, that is also essential for political reasons, as the shortage of fossil energy sources will inevitably increase political instability and conflicts.

Fortunately, the earth is not a closed system, since it receives energy from the sun in the form of light. The solar energy that arrives on earth in one hour is equivalent to the annual total world energy consumption. This simple consideration indicates that solar energy is the only answer to our pressing energy demand in the long term. However, photovoltaics and other renewable energy sources that are derived indirectly from solar radiation are not expected to be sufficient for fulfilling the increasing energy needs of our civilization. We have to develop new methods to convert solar energy into fuels, and thus into chemical energy. From this point of view, the role of chemistry is fundamental.

The present book is extremely timely: it is essentially focused on front-line research aimed at making the conversion of solar energy into chemical energy a real possibility by solving the problems associated with the fluctuation and low intensity of solar radiation. The book, introduced in a lucid preface by the editor, Robert H. Crabtree, who is one of the top world leaders in the field, is appropriately divided into two parts, the first one devoted to energy production and the second centered on energy storage. The first chapter, by Navarro and co-authors, reviews the state of the art in the production of hydrogen from renewable sources, and describes the possibilities offered by biomass and other indirect forms of solar energy. The second chapter, by Ulas and Brudvig, is centered on energy conversion in photosynthesis, and describes in detail the methods that nature has developed to accomplish the difficult task of converting solar to chemical energy. The chapter helps the reader to understand crucial steps in the chemistry, such as multielectron transfer processes.

Since the photochemical splitting of water is considered a possible method of solar energy conversion, many of the chapters deal with photoinduced oxidation of water, which is the most difficult chemical problem that must be solved to achieve an efficient water splitting process. The chapter by Llobet and Romain reviews the molecular catalysts that have recently been identified for oxygen production from water, with emphasis on ruthenium, cobalt, and manganese compounds. The chapter by Ott and co-authors highlights the progress towards the production of solar fuels using a biomimetic approach investigated by the Swedish Consortium for Artificial Photosynthesis. In the chapter, both approaches for light-driven water oxidation and for H_2 production from water are presented. Photocatalytic production of hydrogen from water is the main theme of the chapter by Arachchige and Brewer. The problem faced here is to design supramolecular multimetallic complexes that are capable of performing a multielectron collection function on a succession of photoinduced one-electron transfer processes. The chapter by Batista introduces a theoretical viewpoint, stressing some computational challenges in energy research. Methods aimed at the simulation of interfacial electron transfer at semiconductor surfaces are reported, as well as the intriguing aspects of proton-coupled electron transfer and rectification of interfacial electron transfer. An informative chapter on dye-sensitized solar cells, by Andrade and colleagues, gives an overview of this promising area of research. The chapter explains the basic concepts, and provides clear and detailed discussions of aspects related to photophysics, electrochemistry, semiconductors, and electrolyte effects. Somewhat related to that topic is the excellent chapter by Ardo and Meyer, which deals with photo-initiated electron transfer at the interface between TiO2 and transition metal polypyridine complexes. Like the previous chapter, this one too



Energy Production and Storage
Inorganic Chemistry Strategies for a Warming World. Edited by Robert H. Crabtree. John Wiley & Sons, Hoboken 2010. 428 pp., hardcover, € 149.00.—ISBN 978-0470749869

is centered on dye-sensitized solar cells, but here the focus is on the photosensitizers and on the photoinduced electron injection processes. The solar light-harvesting efficiency of various dyes is investigated, and the authors discuss the choice of ligands used, with regard to their effects on light-harvesting efficiency and recombination events.

Water splitting is not the only way to convert solar energy into chemical energy, and other chapters deal with promising processes such as methane-to-methanol conversion, which is discussed by Hashiguchi and co-authors, who review the various coordination metal complexes involved as catalysts in this important process. The electrochemical and photoelectrochemical conversion of carbon dioxide to alcohol is discussed by Crabtree, who also reports in his chapter some broad conclusions about the difficulties and perspectives related to electrocatalytic (or photocatalytic) processes for the reduction of CO_2.

The "Energy Production" part of the book also includes chapters dealing with fuel cells, as the optimization of fuel cells is obviously a key point for the effective use of solar fuels. Barrière introduces a biologically-orientated approach, and discusses the use of enzymes and microbes in fuel cells, including a review of research on microbial catalysis in microbial fuel cells. The selection of materials and their processing for intermediate-temperature solid oxide fuel cells are at the center of the chapter by Atkinson and co-authors, who also report on approaches to reducing the costs of materials for the production of fuel cells. The important topic of proton exchange membranes in fuel cells research is covered by Devanathan, who also discusses the degradation of such membranes, and Chia and Lee report work on direct ethanol fuel cells. Lastly, Oyaizu describes a molecular approach to the catalytic performance of fuel cells.

The "Energy Storage" section begins with an excellent chapter by Wells and colleagues, who compare key technologies for hydrogen production from various points of view, including costs, current use, and theoretical potential. Future prospects for a hydrogen energy economy are also presented. The potential of lithium ion battery electrolytes is reviewed by Lucht and co-authors, and materials aspects connected with the properties of supercapacitors, in connection with the principle of energy storage in supercapacitors, are extensively discussed in the chapter by Zhang and colleagues. These authors also report on the potential of relatively new materials such as carbon nanotubes and graphene for use in supercapacitors. Finally, the possibilities offered by thermochemical water splitting are discussed by T-Raissi, and basic investigations on molecular materials for lithium ion batteries, essentially based on NMR studies, are described by Cabana and Grey.

In conclusion, this is a well-balanced book, covering most of the approaches to the problem of the production and storage of energy from renewable sources. The presentation is excellent, with most chapters well provided with references and illustrated by informative figures. Almost all chapters end with future perspectives and with summarizing conclusions, which also serve as abstracts. The book is highly recommended for all researchers in the field, and should serve to inspire new researchers to join this extremely important field.

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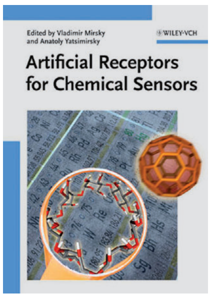
DOI: 10.1002/anie.201103012

Artificial Receptors for Chemical Sensors



Artificial Receptors for Chemical Sensors
Edited by Vladimir M. Mirsky and Anatoly Yatsimirsky. Wiley-VCH, Weinheim 2011. 470 pp., hardcover, € 139.00.—ISBN 978-3527323579

The editors of the book are well-known for authoring monographs such as *Combinatorial Methods for Chemical and Biological Sensors* (Springer, 2009, by V. M. Mirsky) and *Principles and Methods in Supramolecular Chemistry* (John Wiley & Sons, 1999, by H.-J. Schneider and A. K. Yatsimirsky). The content of this new book lies at the interface of sensors and supramolecular chemistry, and equally addresses readers in both areas. The goal was to discuss artificial receptors with an emphasis on their practical applications as components of chemical sensors and arrays. It comprises 14 chapters, each written by exponents in their field. References up to the year 2009 are included, such that the book is one of the most up-to-date resources in an area, where already several counterparts exist. These are, however, frequently more involved with engineering aspects, for example, *Chemical Sensors—An Introduction for Scientists and Engineers* (Springer, 2007, by P. Gründler), *Analytical Techniques in the Sciences: Chemical Sensors and Biosensors* (John Wiley & Sons, 2002, edited by B. R. Eggins), and Janata's *Principles of Chemical Sensors* (Springer, 2009).

It is one of the books, which a curiosity-driven researcher would start to read from the end: Chapter 14 tabulates binding constants of artificial receptors, 58 of them, with many analytes. The table is naturally incomplete, although the back-cover summary claims otherwise. For example, it lacks stoichiometric analyte binding by simple unmodified macrocycles such as sulfonatocalixarenes and cucurbiturils. However, it presents a

