l'actualité chimique
LIVRES

RADIATION CHEMISTRY

FROM BASICS TO APPLICATIONS IN MATERIAL AND LIFE SCIENCES

EDITED BY :

Mélanie SPOTHEIM-MAURIZOT,
Mehran MOSTAFAVI,
Thierry DOUKI,
Jacqueline BELLONI

EDP SCIENCES

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COLLECTION DIRECTED BY **Paul RIGNY**

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Foreword

"L'Actualité Chimique" is a monthly scientific journal meant to convey information on progress in the chemical sciences to a public endowed with a certain ability to master scientific matters. The articles were written by scientists who took time out of their laboratories to explain their studies and their knowledge with a pedagogy and an appeal suitable for non-specialists. Mostly written in French, it creates a bond in the chemical community in French-speaking countries where it is very much appreciated by scientists, teachers and engineers.

However, the scope of the journal implies some limits that we want to erase with this new collection "L'Actualité Chimique – Livres", which will be complementary in two directions: the first one is illustrated by the present book, as it addresses readers more specialized than the journal usually does, and being written in English, it has the ambition of attracting attention worldwide on a field of chemistry where recent progress is noted. The second direction that will be found in the new collection is, in contrast, that of disseminating the progress of chemistry for the benefit of a large, French-speaking, not necessarily professional public. The first trend will produce books that we will find in many laboratories; books produced according to the second trend will instead be largely found in public libraries, in schools or even in the homes of scientifically curious people.

This first volume of "L'Actualité Chimique – Livres" is of the first kind and devotes itself to **Radiation Chemistry – From basic science to applications in biology and material science**.

This field of research is undergoing a true and fruitful rejuvenation. Already active in the mid - 20th century, the development of this scientific field had been somewhat slowed down by the high cost of short-pulse particle accelerators and specialized construction. Recent progress in instrumentation *e.g.* : the shaping of picosecond radiation pulses, faster time-resolved detection techniques, and powerful molecular structure determination techniques, has coincided to enhance the capacity of radiation chemistry sufficiently to warrant new investments and the start of new laboratories. Radiation chemistry today is responsible for major progress in the understanding of the elementary chemical event and powerful enough to unravel the mechanisms of the damage induced by radiation to living matter (a question of great concern in the public) or the transformations induced in irradiated materials.

These aspects are developed in the book by international-level specialists and will be of interest to scientists who are starting in the field, to more experienced ones, and also to students and teachers; it will also be very useful to many professionals who apply or deal with radiation in their activities to improve materials or to avoid radiation-induced damage to them.

Paul RIGNY
Chief Editor of "L'Actualité Chimique"
March 2008

Preface

Radiation chemistry deals with the chemical reactions resulting from the interaction of high-energy photons or particles with matter. Such radiation possesses energy high enough to induce ionisation of the components of the material and the breaking and building of chemical bonds.

In the present volume, our purpose is to familiarise the larger communities of students and chemists in other specialities with this relatively little-known but essential domain of chemistry. The covered topics range from the basics (primary phenomena and mechanisms) to the broad fields of their application. Understanding radiation-induced chemical and biochemical reactions is essential for improving existing processes and developing new ones.

Therefore we have called upon internationally recognized experts who kindly agreed to contribute to this volume with clear, instructive and pedagogically presented chapters abundantly illustrated with attractive colour figures.

The first chapters of Part I deal with primary radiolytic phenomena and describe recent developments at the facilities used to create radiation-induced species, as well as the most advanced methods for their detection and study. The mechanisms of radiation-matter interactions and their consequences for the physical chemistry of liquids and solutions are discussed.

Part II describes specific mechanisms and key processes in space and nuclear chemistry, as well as in material sciences and pharmaceutical and food chemistry. The high energy of ionizing radiation offers the specific advantage of easy and homogeneous sample penetration. Therefore, by targeting chemical bonds at room temperature via cost-competitive, chemical additive-free processes, ionizing radiation can be used for many interesting purposes. For example, thanks to the understanding of radiation-induced nucleation/growth processes, the final size and properties of metal nanoclusters can be controlled for applications in catalysis, electronics, and photography. High-performance polymeric materials, obtained using the cleavage or the formation of chemical bonds by irradiation, have a multitude of uses in everyday life. Remediation of waste-water requires the destruction of toxic chemicals, which is efficiently accomplished by irradiation. The use of ionizing radiation for food treatment and the sterilization of pharmaceuticals and medical devices operate *via* the efficient destruction of micro-organisms, but they require systematic confirmation of the absence of any toxic molecules that could be produced during irradiation.

The search for new means of improving the success of cancer radiotherapy motivates an increasing interest in the chemical mechanisms underlying radiobiology. Part III of the volume is devoted to this very active research domain, and in particular, to studies of the damage induced by ionizing radiation in biomolecules (DNA, proteins, lipids). Answers are given as to what are the mechanisms of the reactions in DNA and other biomolecules following the initial ionization and excitation, how they can be simulated by computational models, how radiation-induced lesions are repaired or prevented, and finally how this improved knowledge is used to specifically eradicate tumours (cancer radiotherapy).

With no pretence of exhaustively covering in detail all the topics of radiation chemistry, this volume will hopefully fulfil the expectation of the reader to learn about a domain that we consider a most exciting and promising area of chemistry.

We cannot end this preface without addressing our thanks to Yann Gauduel and Paul Rigny, respectively former and present Chief Editors of " L'Actualité Chimique", who solicited and accompanied us in the realisation of this work. All the other members of the editorial board of the journal and of EDP Sciences are equally warmly thanked.

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Part I

Primary radiation-induced phenomena

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Chapter 1

An overview of the radiation chemistry of liquids

George V. BUXTON

Introduction

Radiation chemistry is the chemistry initiated by the interaction of high-energy photons and atomic particles with matter, so-called ionising radiation. As a method of generating free radicals for applications in general chemistry the most commonly used sources of ionising radiation are ^{60}Co γ-rays, which are photons having energies of 1.17 and 1.33 MeV (1 eV = 1.6×10^{-19} J), or fast electrons from an accelerator with energies typically in the range 2-20 MeV. The dose absorbed by the material is expressed in grays (1 Gy = 1 J kg^{-1}) and the dose rate in Gy s^{-1}. In each case the result of the interaction of high energy particles with molecules is the ejection of a single electron, called a secondary electron which itself may have sufficient energy to cause further ionisations, but which rapidly (< 10^{-12} s) reaches thermal equilibrium with the liquid and becomes trapped as a so-called solvated electron (e_s^-). In this way, stable molecules (M) are converted into solvated electrons and highly reactive free radicals ($M^{\bullet+}$):

$$M \rightsquigarrow M^{\bullet+} + e_s^- \quad (1)$$

Pulse radiolysis experiments have provided clear evidence for solvated electrons in both polar (water, alcohols, etc.) and non-polar (alkanes) liquids through their optical absorption spectra.

An important characteristic of ionising radiation is that it is absorbed non-selectively so that molecules are ionised according to their relative abundance in the medium of interest.

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