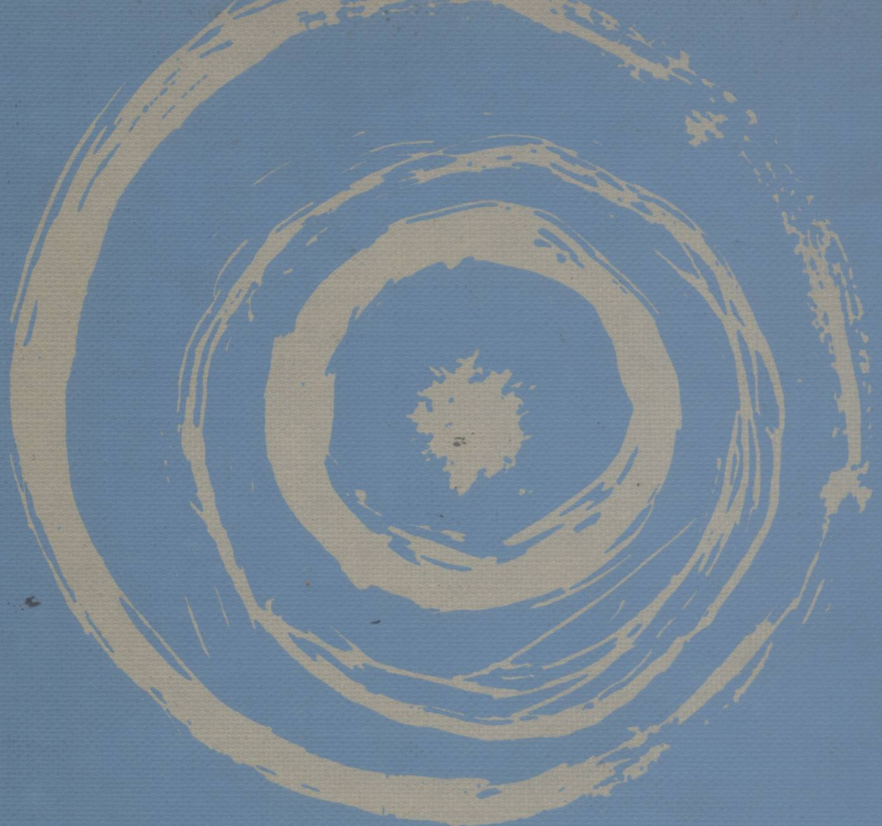

ATOMS, MOLECULES AND CHEMICAL CHANGE

THIRD EDITION

Atoms, molecules and chemical change

RUSSELL H. JOHNSEN
Professor of Chemistry, The Florida State University

ERNEST GRUNWALD
Professor of Chemistry, Brandeis University

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Preface

TO THE THIRD EDITION

ATOMS, MOLECULES and CHEMICAL CHANGE is intended to be a textbook of chemistry for general education. We have tried to achieve a point of view in which chemistry emerges as a subdivision of natural philosophy rather than of technology. Many courses in general chemistry nowadays take the existence of atoms and molecules for granted at the outset, so that time might be gained in which to develop the technical consequences of these concepts. We feel, however, that such an approach is ill suited for general education. Our book traces the gradual development of modern ideas concerning atomic and molecular structure, beginning with the operational definition of a pure substance and ending with modern theories of the nucleus. Throughout the book we emphasize the interplay of theory and experiment and lead from one to the other. We hope that students of this book will end up with a good idea of the experimental and logical foundations of chemistry.

In preparing the third edition we have tried to keep the original approach substantially intact. However, many sections have been rewritten to improve the accuracy or clarity or to bring the material up-to-date. The chapters on Bohr's theory of the hydrogen atom and on covalent bonding have been revised extensively, and a brief chapter on stoichiometry and chemical equations has been added.

The material in this book is suitable for a one-semester chemistry course or (by careful selection of topics) for a one-quarter course. The book has also been used as a text for a one-quarter course devoted primarily to atomic structure, by selection of chapters 1 through 4 (quickly), 5, 8 through 11, 17 and 18.

We thank our wives for their continued encouragement and their help in the preparation of the manuscript.

R.H.J. / E.G.

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The scientist does not study nature because it is useful. He studies it because he delights in it, and he delights in it because it is beautiful.

HENRI POINCARE (1854–1912)

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INTRODUCTION

CHEMISTRY IS the science that deals with the structure and composition of matter and the transformations it undergoes. It is a field of study that has engaged the attention of many people over many years, not only because of the great complexity and variety of matter, but also because of the great perfection with which the chemist wishes to understand it. Chemistry tries to answer such questions as these: What is the make-up or composition of this particular kind of matter? Why does it have certain qualities and not others? Will it undergo changes into new, and perhaps more interesting kinds of matter? Can it be produced through the transformation of other, more plentiful kinds of matter?

Above all, the chemist is interested in the *structure* of matter. He believes that each kind of matter, if it could be examined with sufficient magnification, would be found to have a characteristic structure; and that if enough were known about the detailed structure for enough different kinds of matter, all the individual qualities of matter could be understood. This belief must, in a large measure, rely on faith, because the kind of structure that is envisaged is best described as *submicroscopic:* it is so fine that even the most powerful of microscopes will not render it visible in any direct sense. Nevertheless, it has been possible to derive a remarkably detailed picture of the structure of matter by a variety of indirect means.

A chemist trying to learn about the structure of matter is not unlike a detective on the scene of a crime. He obtains a clue from this set of observations, and another one from that; then he puts these clues together and builds up a circumstantial case. There is one important difference, however. Whereas the detective's reconstruction of the crime involves real persons who can be questioned, and objects that can be observed, the chemist's picture of the structure of matter can never be verified by direct recourse to the human senses. His case must remain forever circumstantial.

The chemist does the best he can to elucidate the structure of matter within the framework set by these limitations. He tries to make his circumstantial case so airtight, to arrive at a unified picture of the structure of matter from so many different kinds of evidence, that no one but a confirmed skeptic could entertain any serious doubt about the picture. This is an ambitious goal. Clues must be used wherever they are found. While much of the information concerning the structure of matter comes from the work of chemists on the composition and reactions of individual kinds of matter, an equally important share comes from the work of physicists, whose business it is to discover and study such aspects as are common to *all* matter. Thus, physics includes such studies as the motion of objects under the influence of a force, the behavior of matter after electrification or magnetization, or the flow of heat from one portion of matter to another when there is a difference in temperature.

The two sciences, chemistry and physics, complement one another. The former tends to concern itself with the specific characteristics of individual kinds of matter, and the latter with general properties shared by all matter. It is not uncommon, therefore, to find chemists and physicists working on different aspects of the same general problem.

Chemistry's role in today's society

The fruits of these efforts of the chemist are many and varied and have had considerable impact on the way in which we live our lives. Much of this impact has been beneficial. We can cite, for example, the plastics industry, or the new types of metallic alloys that have had so much to do with the successful exploration of space, or the types of material called semiconductors that are basic to the manufacture of transistors and have made possible today's large and fast computers. Medicinal chemistry has provided many cures and prevented much disease. Even the aesthetic side of life has benefited from the efforts of the chemist:

new dyes, new colors and new materials have provided the artist with a variety of media undreamed of twenty years ago. The list is large and has been recited often.

Every coin has two sides, however, and with these benefits have come some problems. Plastic packaging materials are convenient and inexpensive; yet their wide use has increased the amount of persistent litter along our highways. New medicinal drugs have produced unanticipated side effects in some patients, and some drugs have had to be taken off the market. Many products developed for peaceful purposes can also be used as instruments for war. Thus, weed-killers used in agriculture have been used as defoliants in jungle warfare, to the chagrin of many chemists.

A spectacular example of "the other side of the coin" is provided by the pesticide, DDT. After the incredible effectiveness of this substance was discovered in 1939, DDT was hailed as a saviour of mankind—it was used to wipe out the malaria mosquito and to boost food production by controlling agricultural pests in many parts of the world. However, today it is obvious that the wide-spread and uncontrolled use of DDT has placed many animal species in danger of extinction and has given man a burden of toxic material that could, under extreme conditions, endanger his life.

Pollution of air and water has now reached a critical level. Chemical and other industries contribute to this directly. Chemical fertilizers that are washed into streams and lakes, and sewage discharged into streams, contribute another type of pollution—one which promotes the growth of algae at the expense of other life and ultimately fouls the water. Automobile exhausts produce a large fraction of the total air pollutants in the U.S. The increase in air and water pollution is the result of increased industrialization and of a growing population (which is, in turn, a result of the greater longevity brought about by scientific technology).

Fortunately, the pollution problems created by technology can be solved by technology—though usually at some cost. Chemistry will undoubtedly play a role in solving these problems. For example, in the case of pollution by automobiles, one can foresee the possibilities of creating better combustion engines or of powering cars electrically (perhaps using new hydrogen-oxygen fuel cells that produce only water