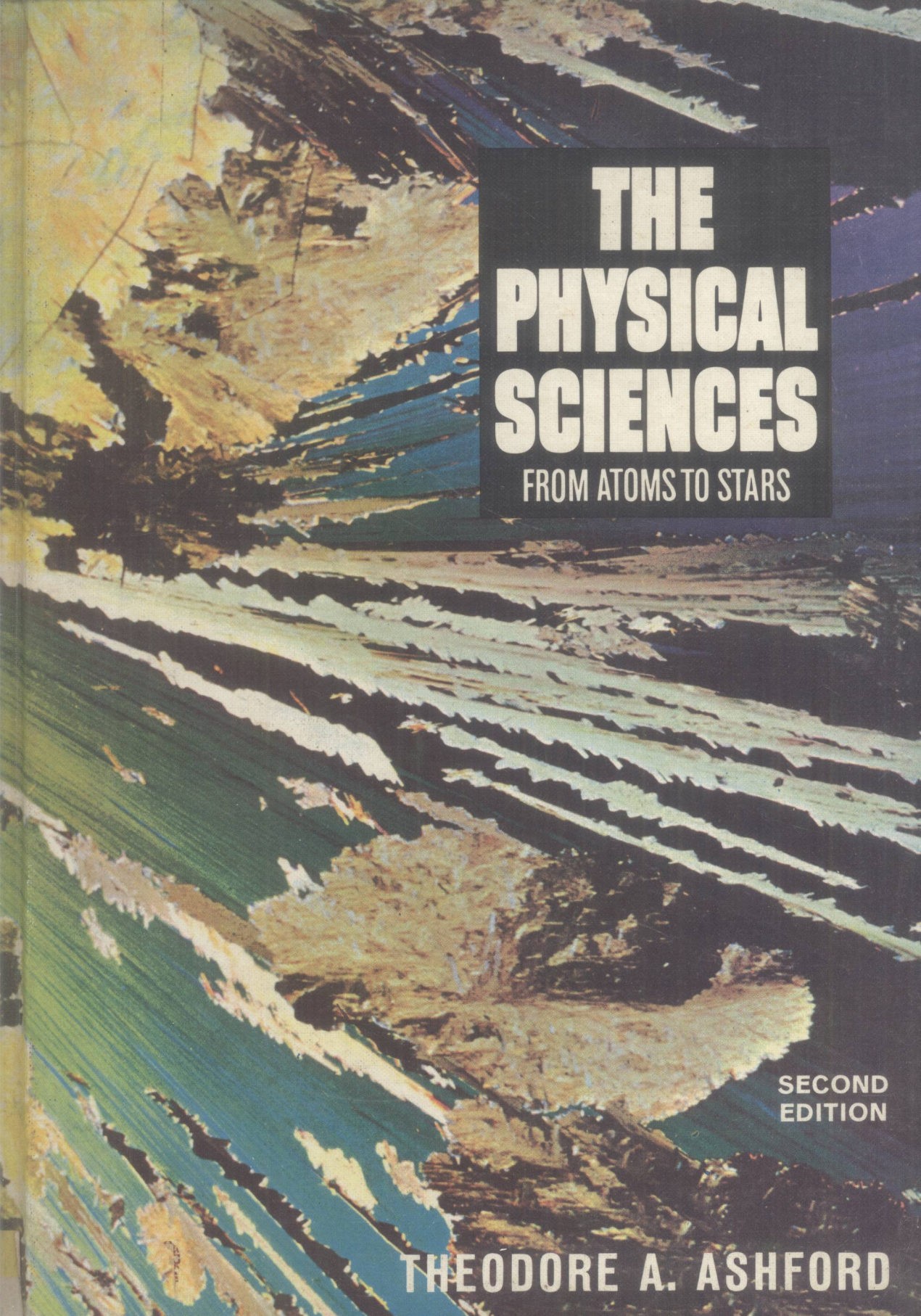
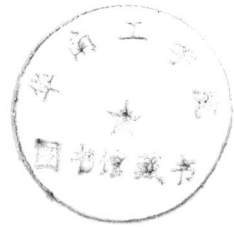

THE PHYSICAL SCIENCES
FROM ATOMS TO STARS
SECOND EDITION
THEODORE A. ASHFORD

The Physical Sciences

FROM ATOMS TO STARS



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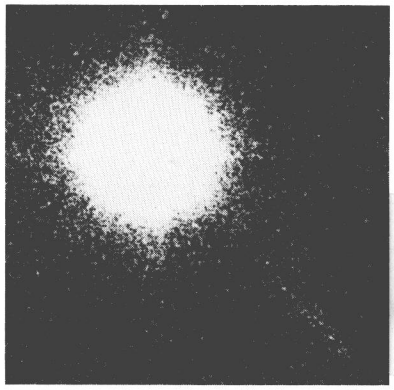

Theodore Askounes Ashford
University of South Florida

Holt, Rinehart and Winston, Inc.
New York • Chicago • San Francisco • Toronto • London

To my wife and sons

(without whose help the book

might have been written many

years earlier, but who have

suffered the most during the period)

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Eloise Stackweather
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Bernard Mitchell Associates

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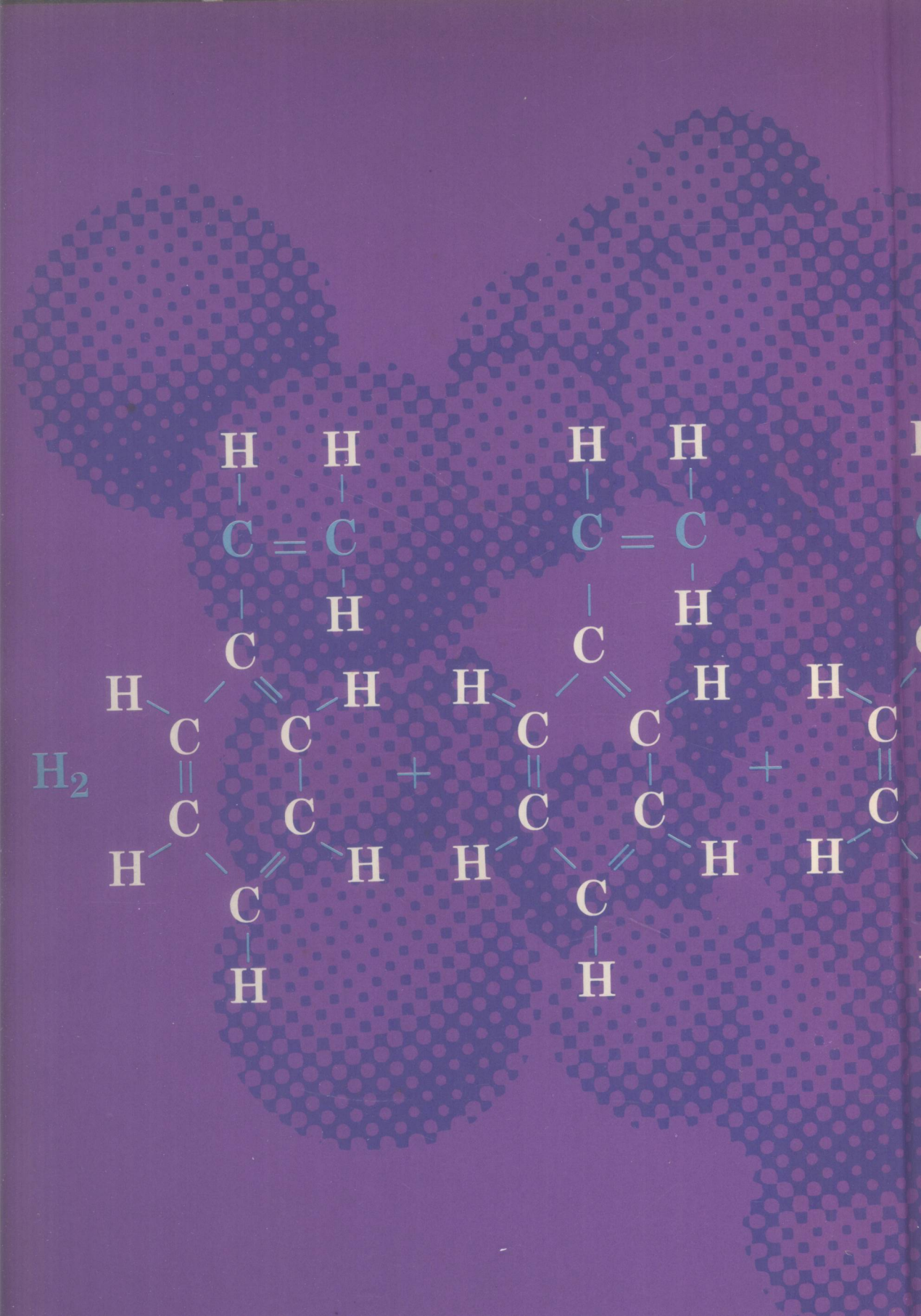
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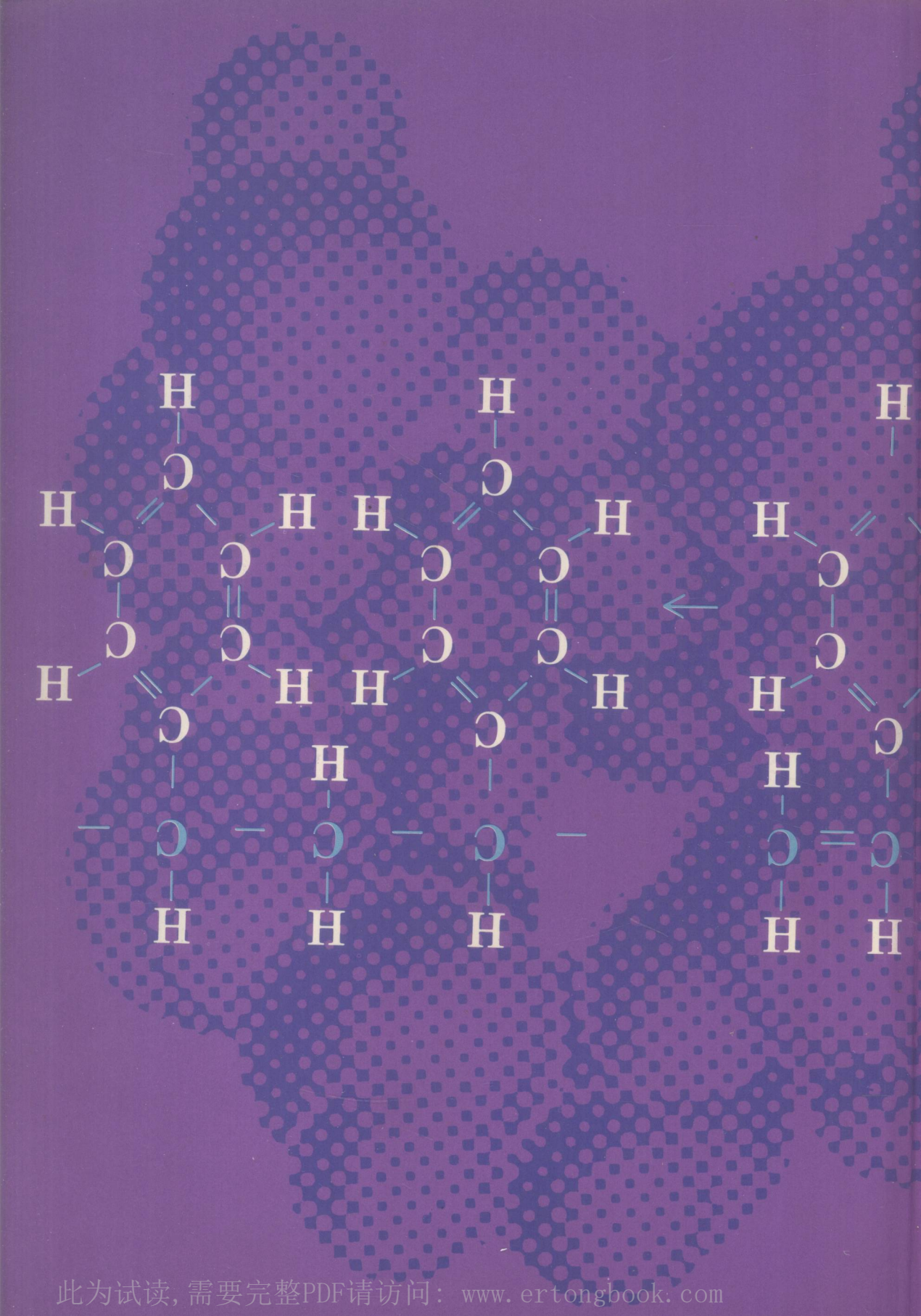
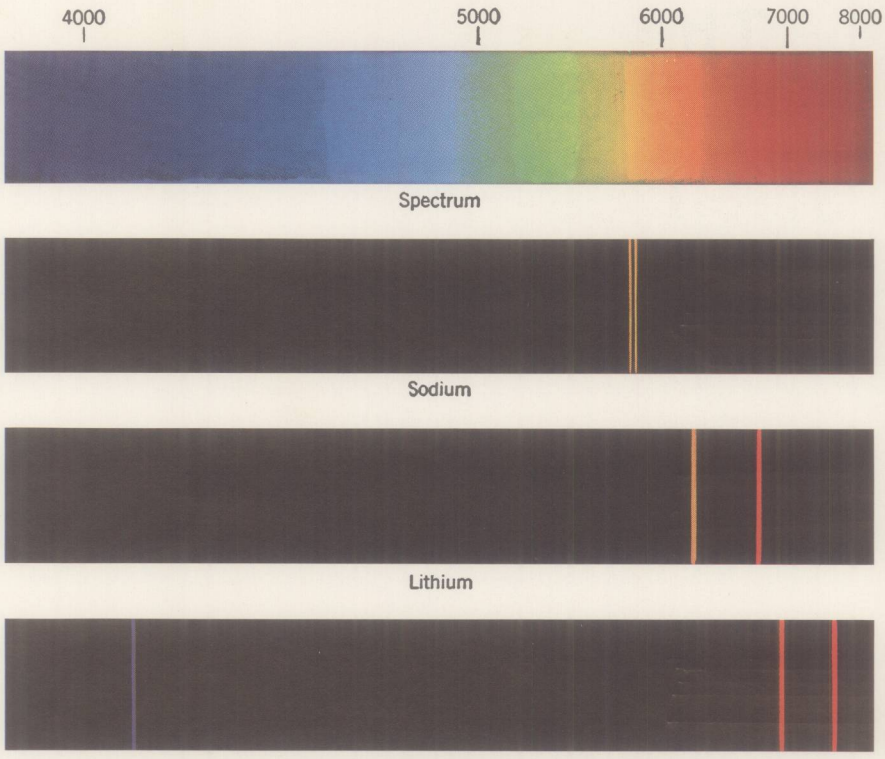
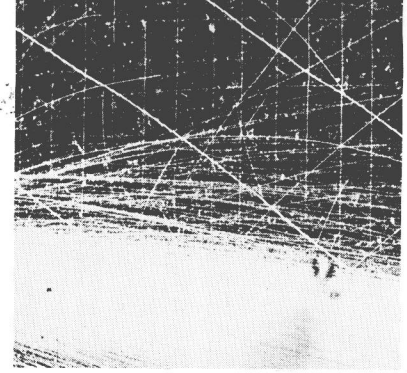


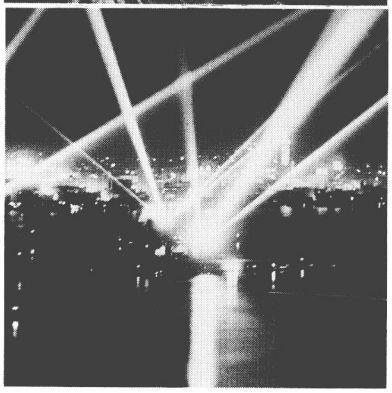


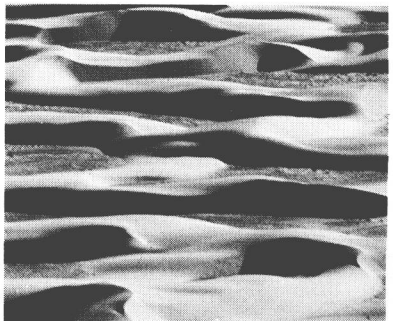
Continuous spectrum as from a body heated white hot (at top), and three bright-line spectra emitted by atoms, as indicated, in hot gases. The numbers at the top are wavelengths expressed in Ångstrom units. (From Dull, Brooks, and Metcalf, *Modern Chemistry*, Holt, Rinehart and Winston, Inc.)

The Physical Sciences

FROM ATOMS TO STARS







PREFACE TO THE SECOND EDITION

The first edition of this book was published under the title "From Atoms to Stars," in 1960. In these brief seven years the swift march of science has rendered numerous parts of the book out of date. In practically every page changes had to be made to incorporate the most recent knowledge.

The most dramatic progress has taken place in space science and in our knowledge of the solar system. Manned space satellites, orbiting of the moon, soft landings of instruments on the moon, close-up photography of the moon, fly-by photographs of Venus and the remarkable photographs of Mars taken by Mariner IV, are all events of this decade. Before the end of the decade, man will have landed on the moon, and even greater progress may be expected.

Major developments have also taken place in other fields of science. The light and radio telescopes have reached deeper into space, recording galaxies 10 billion light years away or more, and receding with speeds over 80 percent that of light. Organized life was detected in rocks over 3 billion years old. The age of the earth has been more closely estimated at nearly 5 billion years, and the probable age of the universe has been pushed back to 15 billion years. More has been learned about the interior of the earth. In chemistry, the inert gases have been found to form compounds. A new scale for atomic weights has been adopted. More accurate measurement of atomic masses have been made. Rapid progress was made in nuclear science and in the understanding of subatomic phenomenon. All this new knowledge has been incorporated in the present edition.

On the other hand, one is impressed with the simple fact that so much of the body of scientific knowledge remains the same. Mechanics is still the basis for explanations in science. The solar system is still essentially as conceived by Newton. We still speak of wave and particle properties of light. The atomic theory is still the fundamental explanation of the behavior of matter. The number of chemical elements remains at about 100. The earth is still of the order of a few billion years old. The noble gases are still the most inactive elements. The basic structure of science has not altered in the last seven years, nor has the conception of the universe. Underneath the dramatic developments, the basic pattern of science remains the same. This fact gives us some confidence in the essential soundness of the present scientific knowledge.

The author wishes to thank his colleagues at the University

of South Florida, and especially Doctors Richard J. Berkley, Clarence C. Clark, D. Martin Cooper, Heinrich Eichhorn Von Wurmb, Sidney J. French, Wendel J. Ragan and Jack H. Robinson, for their many suggestions and for reading parts of the revised manuscript. He is indebted to many teachers, students and readers, for calling his attention to errors and inaccuracies, and especially to Dr. Anton Postle of the Oregon College of Education; and to his son, Harold A. Ashford for editing parts of the manuscript and for checking references and recent data.

Tampa, Florida
February 1967

Theodore A. Ashford

PREFACE TO THE FIRST EDITION

This book is intended to give the student an understanding of the physical world as conceived by the scientists of our time. It is an extended discussion of some of the phenomena of our physical environment and their interpretation in terms of the ideas and theories of modern science. From the immense quantity of phenomena that occur or have been observed, a limited number have been selected to serve a two-fold purpose. On the one hand, they are representative of carefully observed nature, while on the other they form a basic pattern that can be interpreted by the ideas of science. The familiar phenomena are shown to take on new, and sometimes strange, appearances. The unfamiliar is then interpreted in terms of the familiar. All the phenomena, familiar and unfamiliar alike, are explained in terms of the same set of ideas—ideas that add up to a unified picture of the physical universe.

The discussion is addressed to the student whose primary interest is in a field other than science. All that is assumed is that he have an interest in the world around him. No special mathematical or scientific background is required. For the most part the discussion is carried on in pictorial terms using the arithmetic and geometry of ordinary experience. In few places is more than a knowledge of simple algebra required. The discussion is, however, quantitative and analytical and the student who has a natural or acquired facility for thinking in terms of numbers and quantities will follow the reasoning more easily.

A deliberate effort has been made to strip the subject matter of as much of its technical detail as possible and to ignore the distinctions between the sciences. Consequently, the treatment is integrated aiming at producing a unified picture of our environment without consciously recognizing the various branches of science. The discussion is generally developmental. It is historical in the sense of relating what ideas preceded other ideas, and what discoveries led to new ideas. The emphasis throughout is placed on the methods of science—both of discovery and of analysis.

The text is based on several courses that the author developed and taught in the college of the University of Chicago from 1936 to 1950. These courses were in the physical sciences, designed primarily for general education.

The text was used in manuscript form in a course for graduate students in philosophy, history, and religion at Saint Louis University. Part of the manuscript was used in a class given to high-school chemistry teachers in the Institute for the Teaching of Chemistry sponsored by the National Science Foundation at Saint Louis University.

The author is indebted to his colleagues and students for the development of the ideas and philosophy of the book. Special acknowledgment is due to the following, all former colleagues at the University of Chicago: Herman I. Schlesinger and Harvey B. Lemon, pioneers in the course; Walter Bartky, J. Harlen Bretz, Carey Croneis, Nancy Cross, Robert M. Garrels, William C. Krumbein, Lou Williams Page, Thornton L. Page, Zens L. Smith, Reginald J. Stephenson; members of the advisory committee of the course, James Franck, Maria Goeppert Mayer and Harrison Brown. To Dr. Nicholas D. Cheronis of Brooklyn College, for long discussions on science and science teaching. To Dr. Thornton L. Page for permission to reproduce an excerpt from the "Almagest." To Dr. Robert M. Garrels for the benefit of extended discussion in geology and help in obtaining illustrations.

The author further wishes to express his appreciation to all those who assisted in the writing of the book, especially to the late Dr. George W. Schaeffer at Saint Louis University for the strong interest and encouragement, also to Dr. Schaeffer and the administration of Saint Louis University for lightening the teaching load in the fall of 1957; to James Richter for suggestions in designing and executing the illustrations; and to Barbara L. Starkey for the assistance in editing, typing, and preparation of the manuscript.

St. Louis, Missouri
February 1960

Theodore A. Ashford

CONTENTS

CHAPTER ONE

Introduction

First 500,000 volt air-blast circuit breakers in U.S. commercial service. Evidence of industrial advances in the application of science. (Photo courtesy of General Electric.)

1. SCIENCE IN MODERN SOCIETY

If we were to inquire what characteristic features distinguish the present civilization from the other civilizations in the past, we would find one element appearing again and again. This element is natural science. From its early beginnings in the sixteenth century, the development of science has influenced Western civilization more and more, until today it plays a most dominant role in it. It is not much of an exaggeration to say that we live in a world that, materially and intellectually, has been created by science.

APPLICATIONS OF SCIENCE

The point above is easy to illustrate on the material level. We merely need to mention the telephone, radio, television, the automobile, and the airplane, or any of the countless devices invented by the application of science. Similarly, we may mention new materials, new plastics, new metals, new medicines, and, in short, point out the obvious fact that there is hardly an article used in the home, in the places of work, or in the places of enjoyment that has not been modified by technology based on science. The means of communication that bind this continent into a single community depend on scientific know-how; without modern

sanitation it would be impossible to have large centers of population; without modern industry and agriculture it would be impossible to feed, to clothe, and to provide the "abundant life" to this large population. Scientific knowledge underlies the entire industrial and agricultural structure of modern life. America's immense industrial plant requires an army of highly trained men and women for its maintenance alone, to say nothing about its further development.

To National Defense. What does science mean in national defense and war? The atomic bomb, the hydrogen bomb, and intercontinental ballistic missiles come immediately to mind because they have attracted, and rightly so, public attention throughout the world. More recently the military uses of space satellites, space platforms, and detection of missiles below the horizon, have received much attention. But there is much more involved than these developments. World War II was fought predominantly by machines. The battles were really won on the assembly line. For every man fighting on the front, there were 18 men under arms behind him manipulating machines and bringing up supplies; and behind these, 50 million workers forging the weapons of war, producing food, and safeguarding the health and welfare of the fighting men. Behind this formidable working force, there were scientists and engineers, inventing and perfecting radar, proximity bombs, new explosives, new drugs, and countless other devices and materials. This less-well-known story needs to be told and the average citizen should understand it. Nor has the picture altered since the war. If anything, it has become even more sharply defined. So long as the world remains hostile, science is necessary for our national survival.

To Arts of Peace. Turning to the arts of peace, let us examine some facts. In the field of medicine the new wonder drugs have eliminated the dread of many diseases. With the discovery of penicillin and the other antibiotics, the pneumonia death rate has been reduced by 85 percent, that from streptococcus by 60 percent, and all in all, 13 years have been added to the life expectancy of the average citizen. With the development of sanitation, typhus is virtually unknown, and epidemics no longer threaten the large centers of population. Indeed, our large cities would not be possible without modern sanitation methods. The Black Death, which in the thirteenth century wiped out one third of the population of Europe, can no longer be repeated. And the battle goes on in the laboratory.

To Communication. Take the instance of transportation and communication. Not so long ago the only travel on land was by foot or by means of horse or horse-drawn carriages; and on the sea by rowing or by sailboat. The only means of communication was by direct contact or the printed page. Then came the steamboat, the