PHYSICS

AND

MICROPHYSICS

PHYSICS AND MICROPHYSICS

by

LOUIS DE BROGLIE

De l'Académie française, Secrétaire perpétuel de l'Académie des Sciences

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With a Foreword by

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FOREWORD

THIS is a unique book. It was de Broglie who first recognized the close physical and formal relationship between the quantum states of matter and the phenomena of resonance, at a time when the wave nature of matter had not yet been discovered experimentally.

The presentation of molecular physics of the last decades with its startling experimental results and creative theories should broaden and deepen the scope of every reader.

What impressed me most, however, is the sincere presentation of the struggle for a logical concept of the basis of physics which finally led de Broglie to the firm conviction that all elementary processes are of a statistical nature. I found the consideration of Bergson's and Zeno's philosophy from the point of view of the newly acquired concepts highly fascinating.

The author combines his creative talents with clear critical and philosophical thinking.

ALBERT EINSTEIN.

TRANSLATOR'S NOTE

THROUGHOUT the translation the original has been adhered to closely except for a few places where free renderings have been necessary to make the presentation more suitable for non-French readers. Inevitably with a book on such a subject some of the matter has required modification since the original publication, but notes at the ends of the chapters indicate such cases. These translator's notes are indicated by numbers in the text, and are collected correspondingly numbered at the end of each chapter. Notes at the foot of the text pages are by the original author.

With the approval of the author Chapter XII, "Un Glorieux Moment de la Pensée Scientifique Française" has been omitted, and Chapters IX, XIII, XIV and XV have been summarized. The last three of these chapters deal mainly with the practical application of science to technology and in this respect differ essentially from most of the others which are chiefly concerned with pure science.

Soon after the translation was started additional matter was sent by the author to be inserted at the end of Chapter VIII. It was felt, however, that the second part of this, "On the Statistics of the Pure Cases in Wave Mechanics and the Interference of Probabilities", was more suitable for an Appendix. While most readers will find it both interesting and useful, others may find it rather difficult and in such cases it can be ignored as it is not absolutely essential for understanding the other additional matter of Chapter VIII.

I am greatly indebted to Mr. P. J. Melotte for his most valuable assistance in reading the typescript, galley proofs and page proofs, in which he made a considerable number of suggestions and amendments. I am also indebted to Mr. A. J. Pomerans, who read the galley proofs and suggested a number of alterations which clarified the translation. Lastly, I must acknowledge the kindness of Dr. J. Wishart, Statistical Laboratory, Cambridge, for reading the galley proof of the Appendix and for a number of suggestions.

January 1955. M.D.

AUTHOR'S PREFACE

THE present volume combines a series of expositions or lectures on the subject of physics, scientific philosophy or of the history of the sciences.

The title of this work *Physics and Microphysics*, was chosen with the intention of stressing the formal opposition between two kinds of physics. First, there is the physics of phenomena on the large scale where the classical ideas of localization in space and time, of determinism, and of the individual object, are fully valid. Then there is the physics of the atomic and corpuscular scale where, as a sequel to the necessary intervention of the quantum of action, these ideas are obscured and subject to revision. In a prior work a number of points have been discussed amongst which the following are worthy of notice:

It has been shown in what way the leading ideas of physics and microphysics are contradictory to one another, and how it is that the picture which microphysics uses to describe the phenomena directly perceptible to our senses, constitutes only the statistical aspect of an immense number of elementary processes for which these pictures are not valid. A new general résumé of these questions is to be found in the chapter of the present book entitled *Revelations of Microphysics*, and certain special points are reconsidered in other chapters contained in the work.

A branch of physics that has developed with lightning rapidity during about the last fifteen years is the physics of the nucleus. After some wonderful discoveries this new science has made possible the utilization of atomic energy in conditions known to all. In this volume there is no account of the sequel to the remarkable investigations, of which a large number were carried out in France, which have rendered possible the manufacture of the atomic bomb. For some months much has been written on the subject and other savants should be more competent than the present writer to deal with it in detail. On the other hand, I have attempted, especially in the first two chapters of the book, to draw a picture of the new conceptions to which the developments of the physics of the nucleus have led scientists in these last years—conceptions still being developed but already of great interest. At the end of the book will also be found some views on the consequences which the conquest of atomic energy may have for the future progress of science and for the future of human civilization. The prodigious increase of power which nuclear physics is going to place at the disposal of men raises, in the moral as well as in the material realm, problems which are grave and even distressing, and which no one at the present time can afford to disregard.

The author of this book, although he has worked in laboratories at certain periods of his life, is a theorist. The researches which led him in past years to propose the first bases of wave mechanics were of an essentially speculative nature. So it is not without a certain amount of surprise that he has seen, within a few years, the conception of wave mechanics lead to some techniques of the highest practical importance, such as electronic optics and the analysis of small structures by the diffraction of electrons, techniques which are outlined in Chapter VI. The establishing of these unforeseen repercussions of the new concepts of wave mechanics has led attention to the close relationship which exists between the discoveries of pure science and the progress of applied sciences and of technology. The reflection of this prepossession will be found in various parts of the work.

Certain studies of an historical nature also figure in this exposition; those which bear on the contemporary period are partly based on personal recollections. The history of the sciences has always seemed to me to be of great importance for a full understanding of their present state. Many of the scientific ideas today would be different from what they are if the paths followed by the human mind to reach them had been different.

The history of science is, moreover, one of the most enthralling branches of general history, for it gives us a balanced view of that great and perilous adventure which, by continually enlarging the perspective of our thought, and by completely transforming the conditions of our life, hurries us with ever-increasing tempo towards a mysterious future.

First Part

SCIENCE

CHAPTER I

THE ELEMENTARY PARTICLES OF MATTER AND THE NEW THEORIES OF THE NUCLEUS OF THE ATOM

I PROPOSE to explain the present state of our knowledge of the elementary particles of matter and also to express some views on contemporary theories of the atomic nucleus. Before coming to the core of my subject, however, it is essential to present an outline, necessarily very brief, of the successive discoveries which have enabled physics to reach its present position.

The Atomic Hypothesis

We know that the atomic hypothesis, previously adopted in a somewhat vague form by the ancient philosophers, has been restated in a more precise form by the chemists and physicists of the nineteenth century, and that it has received an ever-increasing number of verifications.

It was the chemists who first introduced in a systematic form the conception of the atom into modern science. The study of chemically well-defined bodies led to their division into two quite distinct classes; the "compound bodies" which could be broken up into simpler bodies by appropriate chemical reactions, and the "simple substances" or "chemical elements" which resist every effort to decompose them by chemical means. The study of the quantitative laws (the law of constant proportions, the law of multiple proportions, etc.) according to which elements unite to form compounds, gradually led the chemists to adopt the following hypothesis: "An element is formed of small particles which are all identical, and which are, by definition, the atoms of that element. Compounds are formed by molecules constituted by the union, in a constant proportion, of the atoms of the constituent elements." This hypothesis was supplemented by another one suggested almost simultaneously—about 1815—by Ampère and Avogadro, and which is stated as follows:

"A gramme-molecule of any pure body (which occupies in the gaseous state, according to Gay-Lussac's Law, 22·3 litres under normal conditions of temperature and pressure) always contains the same number of molecules, whatever the body may be." This number, which is of primary importance for atomic physics, is called "Avogadro's number" or "Loschmidt's number".

We know that after many contentions, often very animated, the atomic hypothesis ended in a triumph and was accepted by all chemists. Today it serves as a basis for all our interpretations of chemical reactions and of the use of formulae explaining the constitution of molecules and their transformations in the course of chemical reactions.

The atomic hypothesis very soon entered the domain of physics where it provided explanations of an ever-increasing number of the properties of matter. The kinetic theory of gases, in assuming that a gas is composed of an enormous number of atoms or molecules endowed with rapid and random movements, has succeeded in interpreting the ideas of pressure, temperature, specific heat, etc., and also has led to the rediscovery of the fundamental laws which connect these quantities. Generalizing the results of the kinetic theory of gases, statistical mechanics has been able to provide a general interpretation of the idea of entropy and to interpret many properties of matter. Finally, it was the physicists who succeeded in providing direct proofs of the real existence of atoms. They arrived at this in studying especially the phenomena of flux, of Brownian and other movements which clearly show the discrete nature of matter, and also by accurately measuring Avogadro's number, by various methods. The agreement thus obtained of the values of this fundamental number, in particular in the noted experiments of Jean Perrin, has led to a conclusive proof of the existence of atoms.

I shall here recall that the hydrogen atom is the lightest of all, and as the Avogadro number is approximately $6 \cdot 10^{23}$, it is deduced that the hydrogen atom has a mass of about $1 \cdot 66 \times 10^{-24}$ gramme. It is known at present that there are ninety-two elements[1] which can be arranged in a series—Mendéléef's periodic series—in which the sequence of the elements corresponds almost exactly with the order of the increasing atomic