Study and Research in Physics.[1]

By Sir ERNEST RUTHERFORD, O.M., P.R.S.

IT is little more than fifty years since special laboratories began to be built, generally on a small and modest scale, for study and research in experimental physics and for the practical instruction of students. During this period, physics in Bristol has been represented by three professors, first for a short time, by the late Prof. Sylvanus Thompson, whose contributions to science will long be remembered, then by Prof. Chattock, who is held in high esteem by all his students for the efficiency and inspiration of his teaching. On his retirement he was succeeded by his pupil, Prof. Tyndall, and I am sure that it is not entirely an accident that this splendid laboratory, which we open officially to-day, had its inception and completion during his tenure of office.

I have always felt a certain bond of union with the University of Bristol, partly because your Council has thought fit to select as your teachers some of my friends and colleagues of other days, and partly also because I have always had a special interest in certain lines of research that have been carried on in the Physics Department. I refer to the investigations made here on the passage of electricity through gases, with special reference to the nature and life history of the charged ions which transport the electric current.

In my youthful days, when I was working as a research student in the Cavendish Laboratory in Cambridge, one of my first essays in investigation, under the guidance of Sir J. J. Thomson, was a study of the way in which a current passes through a gas which is made temporarily conducting by the action of X-rays. It was found that this weak conductivity could be ascribed to the production in the electrically neutral gas of positively and negatively charged carriers, or ions, as they were termed, which moved in opposite directions in an electric field. Information on the nature of these ions was obtained by observing the average speed of these ions when acted on by an electric field.

Although my work in later years has been in other directions, I have always retained a lively interest in this subject, and I well remember my excitement and pleasure when I read in the *Philosophical Magazine* for 1899 a paper by Prof. Chattock giving an account of an ingenious and powerful method for studying the mechanism of the discharge from electrified points, which is always accompanied by the long-known phenomenon of the electric wind. He was able to show definitely for the first time that the discharge was carried by a stream of charged ions, identical in character with the ions produced in the same gas by the action of X-rays. These experiments not only disclosed the mechanism of the simplest form of electric discharge, but also showed us in a convincing way that the nature of the ions was the same, whatever the process causing the ionisation.

If time permitted, I should have liked to direct your attention to the extraordinarily interesting and varied phenomena which underlie the discharge of an electroscope by the action of X-rays or radium rays. Since 1896 this subject has been investigated by a large number of workers in all parts of the world, and no one has contributed more to our knowledge in the early days than my old friend, Prof. Langevin, whom we welcome as our guest to-day. I must also particularly mention the researches in recent years on the life-history of an ion, the avidity with which it seizes on the molecules of water added to a dry gas, and the still greater avidity for the heavy molecules of alcohol and the consequent sluggish movements of the loaded ion. On this aspect of the almost human behaviour of the gaseous ion, the researches of Prof. Tyndall and his students have given us most valuable information.

At first sight, it might well be thought that a study of the mechanism of the discharge of a gold-leaf electroscope under the influence of ionising radiations, however interesting it might prove to the scientific investigator, could be of little importance to the advance of science as a whole and of no obvious practical application. I have, however, taken this example of pure scientific research to illustrate the remarkable consequences that may sometimes follow the detailed study of an apparently trivial and small-scale phenomenon, made with no other object than to understand the processes of Nature, and I am sure in most cases with little idea of the important results that were ultimately to accrue both to science and industry.

In the first place, the ionisation of a gas by radium and X-rays gave into our hands a weapon of great power and range for studying quantitatively the nature of X-rays and the rays from radioactive bodies. This has been largely instrumental in unravelling the wonderful sequence of transformations that occur in radioactive matter, and has led to the discovery of more than thirty new unstable elements. In the second place, the information obtained of the mechanism of the passage of a current under the simplest condition could be at once applied to more complicated forms of electric discharge. It was soon recognised that the beautiful and varied phenomena which are observed when an electric discharge passes through a gas at low pressure was a consequence of the ionisation of the gas by the strong electric fields, similar, but more complicated than the discharge from a needle point. One of the first results of this study was the discovery of the electron, that mobile entity which we now know is one of the ultimate units in the structure of all atoms. Nor must we omit to mention the remarkable consequences that have followed the detailed analysis of the positively charged ions or positive

[1] Address delivered on Oct. 21 in opening the Henry Herbert Wills Physics Laboratory, University of Bristol.

rays that are always present in the discharge. In the hands of Sir J. J. Thomson and Dr. Aston, this has given us a method of precision for studying the isotopic constitution of the elements and for measuring the relative weights of the individual atoms with a certainty and an accuracy that would have appeared quite impossible a few years ago.

It would take me too long to attempt to enumerate to you the great additions to knowledge that have been gained by a study of the effects of swiftly moving electrons and ions produced in a vacuum tube in exciting radiations visible and invisible. Indeed, it is true to say that a large part of the scientific advance in physics in the last thirty years may be traced as an almost direct consequence of the observations on the ionisation of a gas by X-rays. I must, however, refer in passing to the great importance to science and industry of the emission of electrons from glowing bodies—a type of unipolar ionisation—that has resulted in the development of electric oscillators for radio-telegraphy of wonderful power and flexibility, and receivers for magnifying weak currents which have rendered possible the remarkable advances in wireless and broadcasting in recent years. In another direction, too, the effect of light in causing the emission of electrons from bodies—the so-called photo-electric effect—is the foundation of methods for transmitting pictures to a distance, and no doubt before long will give us television on a practical scale.

I hope I have made clear to you by this example the importance of encouraging in our laboratories fundamental research quite apart from any question of their possible application to practical ends. We live in an age when not only do many of the great industries, but also the Government, recognise the importance of the application of scientific methods for the rapid development of industry. Fortunately in Great Britain the Department of Scientific and Industrial Research is alive to the importance of fundamental research in our university laboratories, and by grants and other ways encourages the training of promising students in research method. It also in some cases assists—and I hope will long continue to assist—some of our university laboratories in prosecuting important fundamental researches which are on too costly a scale to be undertaken without financial strain on the slender resources of our universities and other scientific institutions.

Since the War there has been a notable increase in the number of scientific men who are engaged either in fundamental research or in applied research with special reference to industrial problems. The question thus naturally arises as to the nature of the research work that should be carried out in a laboratory like this. Should the spare time of its teachers and research students be devoted to investigations on the fundamental problems of physics, quite apart from any question of immediate practical bearing, or to researches of a character likely to be useful in industry? This is an important question, but I should unhesitatingly say that our pure science laboratories should in the main be set aside for fundamental research. Apart from the interest and importance of adding to our knowledge of the processes of Nature, experience has shown that discoveries of the greatest significance to mankind, whether in the practical or intellectual sphere, are generally the outcome of fundamental research undertaken purely with the aim of adding to knowledge. Industrial research should be undertaken by manufacturers or the Government in special laboratories where the research workers can come into close contact with manufacturing conditions. This does not exclude the desirability of occasionally conducting applied researches in university laboratories, especially where one or more of the staff may have a special knowledge of the problems involved. In general, however, I should view as an unmitigated disaster the utilisation of our university laboratories mainly for research bearing on industry.

When I look back over the thirty or more years of my connexion with research, I am conscious that I have always been looking for a breathing-space when, for a few years, no advances of consequence would be made; when I should gain an opportunity for studying in more detail, at my leisure, the ground already won. Alas, that breathing-space has never come, and I am sure will never come in my time. It seems to me that the remarkable period of advance in physics, which began thirty years ago with the discovery of X-rays, shows no sign of retardation but rather of an ever-increasing acceleration. It is becoming more and more difficult for the scientific man to keep in close touch with the advances in even a relatively small branch of his main subject, much less to read more than a fraction of the papers that are published in an ever-increasing stream.

This is especially the case at the present moment, when there is not only a rapid advance in experimental knowledge and technique but great activity in theoretical physics. The advent of the new or wave mechanics, with special reference to atomic problems, which promises to give an entirely new orientation to our ideas of the relation between radiation and matter, has much increased the difficulty, for the scientific man has to learn a new mathematical alphabet and language to keep in touch with this remarkable development, for which we owe so much to our visitor, Prof. Born of Göttingen.

While this difficulty is common to all scientific workers in a rapidly advancing subject, it is especially felt in comparatively small and isolated institutions in this country and still more in our distant Dominions. There arises, in many cases, a hopeless feeling that it is impossible to keep abreast with the flood of new scientific results and ideas, or to distinguish the wheat from the chaff. This reacts on the energy and enthusiasm of the scientific worker and diminishes the efficiency of his teaching and research.

This real danger can in part be surmounted by the co-operation and goodwill of our university authorities. If the scientific man is to maintain his intellectual activity and enthusiasm, it is in most cases important that he should be given leave of absence at regular intervals, and encouraged to visit other scientific centres, whether at home or abroad, and to get into personal contact with the workers in his special field. The value of such 'refresher' intervals is difficult to exaggerate, whether to the individual or the institution which he serves. I am sure that there are few scientific men that would not benefit by such opportunities.

At no time in the history of physics has there been a closer co-operation and sympathy between the two great branches of physics, the experimental and theoretical. With the ever-growing complexity of experimentation and technique, it is rare in these days that a scientific man can claim to be proficient in both of these branches. There has thus arisen the need that these complementary divisions should be adequately represented in a Department of Physics. I am very glad to see that this has been recognised in your University by the appointment of Prof. Lennard-Jones as professor of theoretical physics. In addition, the institution of research fellowships to attract to the laboratory young men who have shown marked ability for research is a step in the right direction, and I hope that it will be possible in the near future to add to their number. Under such excellent conditions we may confidently anticipate that this laboratory will fulfil the wishes of the donor by developing into one of our most important centres of training and research.

The University owes much to the public spirit shown by the city of Bristol and to the wise generosity of its citizens. I am sure that all scientific men are grateful to the University and to the donor, Mr. Henry Herbert Wills, whose generous benefactions have made possible the erection and endowment of this splendid laboratory dedicated to the pursuit of scientific knowledge.

Marcelin Berthelot.[1]

By Prof. HENRY E. ARMSTRONG, F.R.S.

THE highest testimony we can give to the genius of a departed colleague is to study his work and its bearings, as in such exercise we are bound to find food for thought and gather inspiration for the future. As one of the older chemists, I would fain bear such slight witness as I may to the effect and value of Berthelot's achievements, being the more inclined to this task from having noticed, in the younger generation, a strange lack of interest in the pioneers who laid the foundations of the science they would master, now so mighty a structure—even a failure to understand the language these pioneers used. Continuity with the past is desirable, if only in order that we may understand the mental attitude of inquirers at the time they undertook their labours and be in a position to evaluate the mental development of their ideas.

Berthelot himself, who seems to have been extremely well read even at an early age, through his studies of the alchemists endeavoured to shed light upon the beginnings of chemistry and has thereby made clear the extraordinary difficulty of the task. Few to-day can appreciate his own rigid attitude towards atomic weights—how it was that he wrote C = 6 and O = 8 almost up to the last. If his intimate story could be written, it would probably be one of a mind ever striving to be scientific, yet held in the thrall of that superhuman force we term conservatism: the force by which our human society is held together and bound—the instinct of the herd—through the exercise of which we alone survive. On the other hand, it also separates us and especially from the past—as each new faith tends to antagonise the mind of its holder against an earlier form.

The rising generation has little if any understanding of the language spoken even so recently as in Berthelot's early days. There are, however, men still alive who knew him, though not at the beginning of his career. Let us hope that these will give us of their best—the details that will enable us to follow his psychological development as a worker. For Pasteur we apparently have this information; the lessons we gain from it are invaluable. We seem to have the clearest understanding of his temperament and to be able to follow the gradual unfolding of his powers: to appreciate the masterly logic of his disposition: to see one continuous line of thought pervading all his labours, above all, his desire to serve his fellows. Berthelot offers a surprising contrast: we know so little of the man. His seems to have been a more universal genius. We are in sore need of some thread of continuity to guide us through the maze of his mind.

No episode in the history of chemical science is of greater interest than that of the discovery of dephlogisticated air by Priestley and the instant appreciation of its value by Lavoisier—conveyed in the magic word 'oxygen,' a word, however, the magic of which is not heard by young ears to-day, even in France. We can, in a measure, put ourselves into Lavoisier's position—our habit of thought still being largely that which he introduced in raising chemistry from an empiric art to a philosophy. We can no longer enter into the spirit of Priestley's work—we cannot even read his language with understanding. He has been commonly regarded as a pure empiric, but it is impossible to give credit to such estimate of his character. Berthelot, indeed, has questioned the truth of his representation of himself as an empiric. There are numerous passages in his works which may be interpreted as proof that behind all his inquiries there was both method and logical purpose, though maybe the purpose of intuition only. In the preface to his collected works (1790), he himself advocates philosophical studies in the following most remarkable passage:

[1] The English original of an 'appreciation' contributed to *Chimie et Industrie* in connexion with the centenary celebrations of Marcelin Berthelot.