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MOLECULAR RAYS

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By

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PREFACE

I have agreed very gladly to Professor Rideal's request to write a monograph on Molecular Rays for the Cambridge Series of Physical Chemistry, because I believe that a connected account of this fascinating study will serve at once to interest an increasingly large company in the experimental results which have been obtained with the method, and to serve as a general guide to the technique to those who themselves desire to use it as a tool in research.

The book has been written strictly from the experimental standpoint, and is intended primarily to give a balanced survey of the whole field rather than a minute examination of its separate parts. Chapter I, which deals with the technique of the production and measurement of the rays has however been given rather more detail than the rest of the book, and contains a considerable body of laboratory experience which was inevitably omitted from the original papers; and it is hoped that this part of the book may consequently be useful not only as a general account of the technical side of the subject but also in a measure as a laboratory manual for those who, without previous experience, are entering on experimental work in Molecular Rays.

The literature up to the end of 1930, with the exception of a few deliberate omissions, has been as far as possible completely covered.

I have very many acknowledgments to render to those who have helped me to make this book. Above all, I have to thank Professor Stern and all those friends, both German and American, with whom I worked in the Hamburg Institute for Physical Chemistry, for help given in the form of unpublished data, original photographs for reproduction, line drawings, and some outspoken criticism. This book contains

much of real value, however, which is due to no single individual, but which has been taken from the common stock of opinion and experience current in Stern's laboratory at Hamburg. To that more intangible source also I would acknowledge my debt.

I have to thank Dr P. Clausing of Eindhoven and Dr T. H. Johnson of the Bartol Research Foundation, in each case for a valuable correspondence: and the latter particularly for the very beautiful pictures reproduced in Plate III; also Dr L. C. Jackson for permission to include an account of preliminary results on active nitrogen, Dr J. D. Cockcroft for the original of Fig. 29, Dr O. E. Kurt for the original of Fig. 51, and the Royal Commissioners for the Exhibition of 1851 for the loan of the originals from which the enlargements of Plate VII were made.

My particular thanks are due to Dr A. Klinkenberg and Dr L. F. Broadway for carrying out a number of laborious calculations at my request, and to Dr Broadway for checking all numerical calculations. Mr S. A. McKay has given me great assistance in the preparation of line drawings and graphs. Dr F. P. Bowden and Dr C. P. Snow have read parts of the manuscript, and have made many valuable suggestions, not always adopted, towards its betterment. Dr W. H. Watson has gallantly read the entire book in proof, and his merciless exposure of the traditional "obscurities in the text" has left me deeply in his debt.

Ewald's *Kristalle und Röntgenstrahlen*, Berlin, 1923 has been of great assistance to me pedagogically in writing Chapter IV; those who have read Ewald's book will realise how much the presentation of parts of that chapter owes to it.

I have to thank the Council of the Royal Society, Messrs Julius Springer, Messrs the Akademische Verlagsgesellschaft, *The Physical Review*, *Physica* for the use of line and half-tone blocks; and the McGraw Hill Book Company for permission

to reproduce Table VI, p. 123, from Pauling and Goudsmit's *Structure of Line Spectra*.

It is with particular pleasure that I record my indebtedness to Imperial Chemical Industries Limited, who have made it possible for me financially to pursue my experimental work and at the same time have the leisure to indulge in the writing of books.

RONALD FRASER

CAMBRIDGE
August 1931

FOREWORD

The investigations which are pursued in the Hamburg Institute for Physical Chemistry, and in which Dr Fraser took part for three years, are concerned with the task of furthering the development of the physical method of Molecular Rays. This task embraces not only the evolution of the experimental technique, but also the exploitation of the characteristic features of the new method, the selection of problems which lend themselves to its attack.

Since Dr Fraser discusses in his book chiefly the experimental aspect of the subject, I would add here some general remarks concerning the second point above.

What are the characteristic features of the molecular ray method? Its directness and (in principle at least) its primitiveness. These characteristics at the same time define the range of the method. That is clearly shown in its historical development.

The method was used initially to verify the fundamental postulates of the gas kinetic theory. Naturally there was never any doubt about their validity; but it was none the less satisfactory that one was able to demonstrate so absolutely directly the linear motion of the molecules, to measure their velocity, and so forth.

The characteristics of the method are still more clearly shown in the next problem attacked, that of so-called space quantisation. The quantum theory required that magnetic atoms should take up only certain discrete positions in a magnetic field. Consequently one was at that time (1921) forced to conclude that a gas composed of such atoms should show marked double refraction in a magnetic field. Experiment demonstrated not the slightest trace of this double refraction, a contradiction which in the then stage of the theory was incomprehensible. The molecular ray method made possible an experimentia crucis. It gave absolutely direct evidence of the discrete positions (or rather components

of the magnetic moment) demanded by the quantum theory. The fact that the method yields directly the terms (energy values in the field) and not term differences as in the optical method, was in this instance particularly important. It is clear that it is precisely the directness and (essential) primitiveness of the molecular ray method which enable it to attack problems of a fundamental character. The latest developments show the same trend. It has been found possible to diffract beams of atoms and molecules at the cross grating of a crystal cleavage plane, and thus to establish directly the wave properties demanded by the new mechanics.

Finally, the characteristics already mentioned are evidenced in a further wide field of enquiry open to the molecular ray method, namely the investigation of molecular properties. If one wishes to investigate the magnetic or electric properties of molecules, then the most obvious and natural procedure is surely this: One takes a beam of molecules, sends it past the pole of a magnet or an electrically charged body, and watches how the molecules are deflected. In the investigation of molecular properties appear as further characteristics of the method its high sensitivity (nuclear moments), and its suitability for the study of the potential fields around molecules and at surfaces, whereby the wave mechanics, with its connection between potential and refractive index of the matter waves, plays a special part.

I hope that I have been successful, as a result of this description, in very rough outline, of the characteristics of the molecular ray method and of its most important problems, in indicating also something of that beauty and peculiar charm which so firmly captivate physicists working in this field. I believe that the new method will in time find far wider application than heretofore, and I hope that the present book will help to further this development.

O. STERN

HAMBURG
July 1931

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