THE AUSTRALIAN NATIONAL UNIVERSITY

RESEARCH SCHOOL OF PHYSICAL SCIENCES

ELECTRON AND ION DIFFUSION UNIT

ANNUAL REPORT 1965

Staff

Head of Unit	Emeritus Professor Sir Leonard Huxley, K.B.E., M.A., D. Phil., Hon. D.Sc., F. Inst. P., F.A.A.
Senior Fellow	R.W. Crompton, B.Sc., Ph.D.
Fellow	M.T. Elford, B.Sc., Ph.D.
Temporary Research Assistant	R.L. Jory, B.Sc., Ph.D.
Research Student	A.I. McIntosh, B.Sc.

General

(1) Staff movements -

Following the award of his Ph.D. degree Dr Jory continued to work in the Unit - initially on a full-time basis as a Research Assistant and subsequently part-time while holding the position of Senior Demonstrator in the School of General Studies. He has now taken a position as Research Associate at Florida State University.

Dr R.W. Crompton spent a period of six weeks overseas on study leave to enable him to attend the IV th International Conference on the Physics of Electronic and Atomic Collisions held in Quebec, and the VIIth International Conference on Phenomena in Ionized Gases held in Belgrade. Three papers on the work of the Ion Diffusion Unit were presented at these conferences, one of them being read by Dr J.A. Rees who was a member of the Unit until the end of 1964.

(2) Visitors -

Professor H. Raether of the University of Hamburg paid a short visit to the Unit following his attendance at the Melbourne International Solid State Physics Conference as an invited delegate.

(3) Technical developments -

The most significant advance this year has been the successful development of a new form of construction for the composite receiving electrode used in apparatuses for measuring the ratio of mobility to diffusion-coefficient. The specifications for the electrode are not easy to meet, one of the most difficult being that the electrode surface, consisting of insulated segments, should remain free of

distortion to within a few wavelengths of visible light over the temperature range 80 to 500°K. An overseas firm specializing in ceramic-to-metal sealing, the technique upon which the electrode design was based, contracted for the work but failed ultimately to meet the specification. Following considerable developmental work, a successful technique was eventually perfected in the Unit, although the low temperature project for which the electrode is required has been put well behind schedule as a result of the difficulties.

Work has proceeded on the construction and evaluation of all-metal ultra-high vacuum systems as part of the programme which will enable those lines of investigation requiring conditions of extreme gas purity to be carried out.

Research Programme

(1) Investigations with gases exhibiting electron attachment -

(a) Experiments aimed at ion identiciation -

As a result of work in our own and overseas laboratories, it has become increasingly clear that a number of investigations on positive and negative ions lose much of their value unless some form of ion identification is possible. Of particular interest to our own work is the nature of the negative ion or ions formed by electron attachment in water vapour and whether or not alkali ions remain unclustered in mobility experiments performed at low field strengths. The development of the quadrupole mass-spectrometer, which is capable of operating at relatively high pressures, has opened up new possibilities in this field and the decision was taken late this year to initiate experiments using this device. A prototype apparatus is nearing completion in which ions which have traversed a time-of-flight mobility apparatus enter a quadrupole spectrometer after having passed through a short differentially pumped region between the two sections. This transition region is necessary to achieve a pressure reduction of the order of ten thousand between the mobility apparatus, which operates at a pressure of a few torr and the mass spectrometer. Should these preliminary experiments prove successful, work will proceed on the development of an apparatus using UHV technology and with the mobility section capable of being operated at low temperature.

(b) Experiment to determine attachment rates for thermal electrons -

A new method of measuring attachment rates has been proposed which is particularly suitable for experiments with electrons with energies approaching the gas molecular energy. It is based on the observed dependence of the distribution of current in a Townsend-Huxley diffusion apparatus on the total current entering the diffusion chamber. The dependence has been shown to arise from a small proportion of

negative ions in the electron stream. A quantitative theory relating the current dependence to the electron and ion drift velocities and the attachment coefficient have been given by B.S. Liley of the Department of Engineering Physics and the apparatus for testing the method is nearing completion. A difficulty in applying the technique is the need to ensure that the stream entering the diffusion chamber is free of negative ions. This is to be achieved by placing an ion filter immediately above the hole in the cathode through which the electrons enter the chamber. Experiments will commence early in the new year.

(2) Energy losses of electrons due to rotational excitation of molecules -

Despite the delay already described in perfecting the diffusion apparatus for measurements at low temperature, some progress has been made in this project. The drift velocity apparatus for the complementary measurements has been completed and is undergoing testing before insertion in the glass envelope suitable for the low temperature measurements. Upon the successful completion of the diffusion apparatus some preliminary measurements were made in hydrogen at 78°K. These experiments indicated a number of deficiencies in the apparatus, the most important being a temperature gradient of about 2°K along the length of the apparatus, due to insufficient depth of immersion, and insufficient accuracy in the low temperature thermometry from which an accuracy of the order of 0.25°K is required. These difficulties have now been overcome. A further difficulty, which had been anticipated, was the serious errors arising from changes of contact potential difference within the apparatus at this temperature. Techniques which have been developed lead to adequate stability at room temperature, but the same order of stability is not maintained following cooling of the tube. These effects require that greater reliance be placed on the calibrating technique using positive ions at low temperatures. Experiments to prove the adequacy of this technique are in progress.

(3) Diffusion measurements at high values of E/p -

Following the development of a complete theory by B.S. Liley (Department of Engineering Physics) and C.A. Hurst (Department of Mathematical Physics, The University of Adelaide) for the distribution of current within a Townsend-Huxley diffusion apparatus when primary ionization and secondary processes are significant, the investigation described in last year's report was extended considerably with very satisfactory results. The application of the method to hydrogen has enabled the ratio of mobility to diffusion coefficient to be determined for the first time without falsification from the effects of ionization. A useful by-product of the experiment has been the demonstration of the predominance of the action of photons in producing secondary emission at the cathode under these conditions, the present method being quite different from that usually used to investigate such processes. Quantitative estimates of the magnitude of the secondary

coefficient were in fact made. The results of this investigation have suggested that there are discrepancies of considerable magnitude in existing analyses of swarm data for electrons in hydrogen in this energy regime.

(4) Experiments to determine the momentum transfer cross-section in monatomic gases -

Some further work to that described in last year's report has been carried out with low energy electrons in helium. Some additional measurements of the "magnetic drift velocity" at very low values of E/p have removed a small discrepancy which existed when comparisons of these data were made with values calculated on the basis of the other transport coefficients. All the data for the three transport coefficients are now consistent to within the accuracy of the experimental results. The energy dependent cross-section which predicts the transport coefficients to within one or two per cent (the accuracy of the experimental data) is thought to represent the best determination of the momentum transfer cross-section at present available. Support for this view is given by the excellent agreement between the experimental values and some very recent theoretical calculations using the distorted wave method.

Work is progressing to extend the technique to other monatomic gases. New drift velocity and lateral diffusion apparatuses are well in advance to enable work on the heavier gases to be undertaken under conditions of adequate gas purity.

Publications

Measurements of Townsend's energy factor k_1 for electrons in carbon dioxide.

J.A. Rees *

Aust. J. Phys. 17, 462 (1964).

The behaviour of free and attached electrons in oxygen.

J.A. Rees *

Aust. J. Phys. 18, 41 (1965).

Transport coefficients for low energy electrons in crossed electric and magnetic fields.

R.L. Jory.

Aust. J. Phys. 18, 237 (1965).

The momentum-transfer cross-section for low-energy electrons in helium.

R.W. Crompton and R.L. Jory.

IVth International Conference on the Physics of Electronic and Atomic Collisions, Quebec, 1965.

Precision measurements of the Townsend energy ratio for electron swarms in highly uniform electric fields.

R.W. Crompton, M.T. Elford and J. Gascoigne.

Aust. J. Phys. 18, 409 (1965).

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* Based on work done while a member of the Department.