6/8

2.1.83

17/1965

THE AUSTRALIAN NATIONAL UNIVERSITY
RESEARCH SCHOOL OF PHYSICAL SCIENCES

ELECTRON AND ION DIFFUSION UNIT

Annual Report to Council for 1964

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.
Research Fellow	J. A. Rees, B.Sc., Ph.D.
Research Students	R. L. Jory, B.Sc.
	I. McIntosh, B.Sc.

During the year Dr Elford was appointed to the post of Fellow. Early in December Dr Rees left the Unit to take up an appointment at the University of Liverpool.

General

(1) Students -

Mr Jory completed his Ph.D. thesis entitled "The Motion of Slow Electrons in Electric and Magnetic Fields". Both he and Mr McIntosh presented papers at the Plasma Physics Conference, held in Sydney in November.

(2) Visitors -

Professor C. A. Hurst of the University of Adelaide and Mr J. L. Francey of Monash University spent several days discussing some theoretical aspects of electron diffusion during which Professor Hurst delivered a short course of lectures. Other visitors to the Unit during the year were Dr J. A. Stockdale who has recently returned to A.A.E.C. from Oak Ridge National Laboratories and Dr I. H. Sloan from the C.S.R. Research Laboratories.

(3) Laboratory arrangements -

Following re-allocation of laboratory space in the Cockcroft building the Unit received 370 sq. ft. of additional laboratory area representing an increase of 40%. This increased area coupled with the provision of a smaller room to serve as a machine room for high precision work has greatly eased the overcrowding which existed previously.

(4) Technical developments -

There has again been a considerable investment of time in the development of ultrahigh vacuum techniques which are required now for three lines of investigation, namely, positive ion mobilities, electron attachment and the measurement of transport coefficients in the inert gases. When the conversion to UHV is complete at least four complete systems will be required. The prototype, an all-metal system with provision for accurate pressure measurement by means of unbakeable capsule manometers isolated from the clean system by a bakeable nullmanometer, has been completed and tested. The unit represents a considerable advance on the glass system already in operation, the main disadvantage of which is its fragility under the somewhat stringent conditions of bakeout.

In conjunction with the design and construction of the vacuum system there have been two developments of considerable importance in the construction of the electron tubes which must also withstand extremes of temperature ($80^{\circ}K$ to $350^{\circ}K$). Following a major investigation involving glass technology a successful technique has been developed for making the grids for mobility tubes to withstand these conditions. Preliminary work has also been carried out on the construction of grids from .001" diam. wire with a comparable spacing between the wires using the same technique. These grids are required for a new method of ion identification which does not require the transfer of the ions to a low pressure region with the likelihood of a change of identity.

The second development has been carried out in conjunction with an overseas manufacturer. A considerably more robust form of mounting for the segments of the composite electrode has been designed which will enable electron tubes

requiring this form of electrode to withstand the temperature range while maintaining extremely close mechanical tolerance which recent work has shown to be necessary. The completed assemblies, for which the high precision machining has recently been completed here, are expected early in the new year.

There have been two other developments of importance. Previous reports have referred to the need for the production of gold-coated surfaces with a minimum contact potential difference from point to point over the surface. While vacuum deposition of the gold layer seems the obvious answer, the production of surfaces of high uniformity is by no means straightforward. Techniques have now been developed which produce surfaces with a maximum contact potential difference variation of 5 mV, an improvement of an order of magnitude on early attempts.

Lastly, the year has seen the provision of a satisfactory method of standardizing pressure gauges to within 0.1%. Methods of standardizing the capsule gauges used in the laboratory, which must cover the range 1 to 500 torr, have been sought for some time. The solution for a major part of this range has been found in an adaption of a commercially made vacuum dead-weight tester.

Research Program

(1) Investigation of gases exhibiting electron attachment -

(a) Water vapour and deuterium oxide vapour -

Further work on the determination of ion mobilities in water vapour has been carried out and the experiments extended to deuterium oxide vapour in the hope of determining the attachment process leading to negative ion formation in the two gases. At the present time the experiments are inconclusive and require further investigation.

(b) Oxygen -

A significant contribution has been made to the study of electron attachment in oxygen. Measurements have been made in the range $0.4 < E/p < 6$ volt $cm^{-1} torr^{-1}$ of the ratio W/D and the attachment coefficient for electrons, and of the

mobilities of at least three species of ions formed by attachment in the gas. The use of the method of measuring electron attachment by analysing the divergence of a composite stream of electrons and ions has confirmed the occurrence of three-body attachment in oxygen at low values of E/p for which there is evidence from one or two other experiments only. Further confirmation was afforded by using a pulsed time-of-flight technique which also provided ion mobility data. The use of this method showed the presence of at least three ion species and gave preliminary results for ion mobilities. Subsequently the mobility tube was operated in the usual way as a Bradbury-Nielsen apparatus to give mobility data of accuracy considerably superior to that hitherto available. Considerable confusion exists in the literature as a result of attempting to identify ion species by their zero-field mobility. Frequently the differences in ion mobilities are small and attempts at identification are made using experimental data in which the scatter exceeds the difference expected between the mobilities. The new data not only exhibits considerably less scatter than earlier data, but in some instances extends to lower values of E/p, thus making the extra-polation to zero field a more reliable procedure. As a result of this work it has been possible to identify the ions with some certainty and therefore to postulate the different processes by which they are formed at various electron energies.

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

Experiments are in progress to determine the ratio W/D and the drift velocity W for low energy electrons in normal hydrogen, parahydrogen and deuterium and also in nitrogen. By using high gas pressures and relatively small electric fields the excess of mean electron energy over mean molecular energy can be kept small so that the electron energy is controlled mainly by the gas temperature. The lowest energies are therefore achieved by making measurements at the temperature of liquid nitrogen. Room temperature measurements of W and W/D have been made for deuterium recently following earlier measurement in hydrogen and nitrogen.

Considerable progress has been made in the preparation of samples of hydrogen considerably enriched in parahydrogen

and in the measurement of the ortho-para ratio. The limiting factor in preparing samples of almost pure parahydrogen is the temperature to which the catalyst can be lowered. At the present time the concentration is limited to the equilibrium concentration at 77°K (the temperature of liquid nitrogen).

It is well known that the reconversion of parahydrogen to normal hydrogen at room temperature is relatively slow for samples stored in glass vessels. The conversion rate has been measured in the presence of metal surfaces to simulate the normal conditions of diffusion experiments and also in the presence of a heated platinum filament, the usual sources of electrons in these experiments. The conversion rate in the first instance was found to be slow enough not to affect the experiments but the extremely rapid rate in the presence of the platinum filament eliminated it as a possible electron source. An alternative source in the form of tritiated titanium, which emits low energy β particles, was tried and found to work satisfactorily.

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

Recent theoretical work both on the theory of diffusing electron streams and on the analysis of transport coefficients in terms of the details of the collision processes has thrown doubt on early measurements of the ratio W/D at high E/p where ionization by electron impact becomes significant. In order to make reliable measurements it is necessary to use gas pressures as high as possible. The application to the diffusion chamber of voltages approaching those at which electrical breakdown occurs therefore becomes necessary. An apparatus specifically designed for these measurements has been built in which the electrodes were profiled to minimize the possibility of breakdown. It has been used successfully at voltages very close to those at which breakdown would normally be expected to occur.

The results of this experiment showed that measurements in this regime are considerably more difficult than had been anticipated, owing to the effect of secondary ionization, (either by positive ions or photons), of which no account had been taken hitherto. B. S. Liley developed a theory to take account of primary ionization and the production of secondary electrons

from the cathode by positive ion bombardment. It seems likely, however, that emission by photon bombardment may predominate, but no theory for this case has yet been developed. Further theoretical and experimental work is required on this problem.

(4) Experimental investigation of electron energy distributions -

This year has seen the successful outcome of the work on the diffusion of electron streams in crossed electric and magnetic fields whereby information can be obtained on energy distributions in electron swarms and on the variation of the momentum transfer cross-section with electron energy. Three separate experimental determinations are required for this work, namely the ratio W/D, the drift velocity W and the ratio W_x/W_z of the transverse to longitudinal drift velocities in the presence of the crossed electric and magnetic fields. Apparatus for this work, consisting of a drift velocity apparatus of high precision and an apparatus enabling the ratios W/D and W_x/W_z to be measured were completed last year and tested exhaustively this year using nitrogen as the test gas. Results from other investigations in this laboratory have been used as standards of comparison for W and W/D but no data is available for W_x/W_z. However the experimental method allows this ratio to be measured over wide ranges of several experimental parameters and the agreement between the results of such measurements is a test of the reliability of the method and the experimental procedures. Excellent agreement has been obtained, with the result that the additional transport coefficient can now be measured with an accuracy only slightly inferior to that for the more commonly and easily measured coefficients W and D.

Following the experiments in nitrogen measurements were made in helium for which no data has been available hitherto from this laboratory. This work has opened up a new field from which interesting developments can be expected. In the energy regime under investigation at the present time, only elastic collisions between the electrons and gas atoms need be considered with a consequent simplification to the theoretical description of the transport phenomena. It has been possible to use the drift velocity data only, in conjunction with an

appropriate computer programme, to determine the variation of the momentum transfer cross section with electron energy and to test the solution using the other ratios of transport coefficients W/D and W_x/W_z. Excellent agreement has been found leading to confidence in both theory and experiment. As a result of this work the variation of cross-section with energy for electrons in helium at low energies is known together with the form of the energy distribution function at any value of E/p in the range $0.04 < E/p < 8.0$ volt $cm^{-1}torr^{-1}$. The work is to be extended to the other rare gases on the completion of the ultrahigh vacuum equipment.

Publications

Crompton, R. W. - "The motions of electrons and ions in gases" Chapter 3 in the book "An introduction to discharge and plasma physics" edited by S. C. Haydon published by the University of New England 1964.

Rees, J. A. - "Measurements of Townsend's energy factor k_1 for electrons in carbon dioxide". Aust J. Phys. 17,462, 1964.

Rees, J. A., and Jory, R. L. - "The diffusion of electrons in dry, carbon dioxide free air". Aust. J. Phys. 17, 307, 1964.