13/1967

THE AUSTRALIAN NATIONAL UNIVERSITY

RESEARCH SCHOOL OF PHYSICAL SCIENCES

ELECTRON AND ION DIFFUSION UNIT

Annual Report for Council, 1966

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.
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GENERAL

(1) Visitors

Professor D.S. Burch of Oregon State University joined the Unit in October as a Visiting Fellow.

(2) Technical developments

An increasing number of experiments require the use of vacuum techniques superior to those which have employed conventional glass vacuum systems, glass stopcocks and demountable seals. As part of the programme to develop adequate techniques, a machine for assembling and sealing vacuum tubes has been designed and built. The electrode structures of many of the tubes are very massive yet require the maintenance of close tolerances; it is therefore undesirable to rotate the tubes horizontally in a conventional glass lathe during sealing. The machine is therefore mounted vertically. The positions of the non-rotating head and tail stocks are accurately and smoothly controlled hydraulically; sealing is accomplished by oscillating the flame carriage through about 300°. A 6" glass envelope can be sealed free of strain in less than ten minutes, thereby reducing the risk of tarnishing the highly polished electrode surfaces.

RESEARCH PROGRAMME

(1) Experiments to investigate electron attachment and the mobility of mass identified ions.

The prototype apparatus for measuring the drift velocity of ions of known identity was completed and a series of tests carried out to determine the values of the design parameters for maximum current transmission and mass resoltuion. These parameters were determined and the design of the final apparatus completed. The apparatus is designed to ultra high vacuum specifications and has facilities to enable measurements to be made at 77°K and lower. The construction of this apparatus is now well advanced. In the meantime, work is continuing on the prototype apparatus in order to obtain additional information on the operation of this type of experiment.

(2) Determination of cross sections for rotational excitation of molecules.

This year has seen a considerable advance in both the experimental and theoretical aspects of this problem.

(a) Experimental

In order to obtain data which can be analysed to yield significant information about the cross sections for rotational excitation it is necessary to make measurements of the diffusion and drift of electron swarms at low temperatures. It was reported last year that a drift tube for measuring the drift velocity W and a lateral diffusion apparatus for measuring the diffusion coefficient to mobility ratio D/μ had been constructed, but that difficulties had been experienced in using the apparatus, particularly at low temperatures. The difficulties were successfully overcome and a series of measurements were made of W and D/μ in hydrogen and deuterium at 77°K. Measurements were also made in deuterium at room temperature. As is the case for other gases the data is characterised by much smaller random errors and higher overall accuracy than are evident in previously published data. Both features are essential for the application of the analyses described in 2 (b).

Attention was then turned to the problem of measuring the transport coefficients in parahydrogen. At the boiling point of liquid hydrogen (20°K) the equilibrium concentration of parahydrogen is in excess of 99%; furthermore this concentration can be maintained for long periods at room temperature provided care is taken in storing the gas. The parahydrogen was prepared by liquefying hydrogen using liquid helium from the School's recently installed helium liquefier. Ferric oxide was used as a catalyst in a specially constructed cryostat, it being essential to prepare hydrogen not only with the highest possible proportion of the para form but also free from contamination by other gases, particularly oxygen (section 5). The problems of measuring the ortho-para ratio, and of obtaining an electron source which does not reconvert the gas to the normal form, were solved previously and were described in an earlier report.

The experiments themselves are believed to be the first which have demonstrated the expected differences in the collisions between low energy electrons and the two modifications of the hydrogen molecule. When the energy distribution of the electrons is controlled to a significant extent by collisions which cause excitation of the rotational levels of the molecules there is a significant difference between the transport coefficients measured in parahydrogen and in hydrogen in its normal form. At higher energies, vibrational excitation controls the energy distribution and the coefficients are thereafter the same in the two modifications.

(b) Theoretical

A computer programme developed by the Westinghouse Research Laboratories for solving the Boltzmann equation numerically has been adapted for use with the IBM 360 computer. With this programme it is possible to calculate any of the transport coefficients provided the cross sections for the elastic and inelastic collision processes are known or postulated. A comparison of calculated and experimental results enables the validity of the energy dependent cross sections to be checked.

The experiments described in 2(a) were done because, at low energies, the data for hydrogen and deuterium are some of the most straightforward to analyse for the influence of rotational excitation. This is particularly true of parahydrogen. The currently accepted cross-sections for rotational excitation do not appear to be consistent with the precise data from our experiments and an attempt will be made to find cross sections which are consistent with the experimental results.

(3) Resonance in the momentum transfer cross section for electrons in helium.

During last year new experimental evidence was published which supported earlier observations of structure in the cross section curve below 1 eV. It therefore seemed worthwhile to see whether the effect of such a resonance could be detected in the transport coefficients measured in our experiments. Since a perturbation of only 2 - 3% was expected it is unlikely that the effect could be observed in any data previously published. By modifying existing techniques, the random errors in our drift velocity measurements have been reduced to less than 0.2% thereby allowing a search to be made for the perturbation without great difficulty. No evidence has been found to support the existence of a resonance. This result is in agreement with recent theoretical analyses of the cross-section; furthermore, the more accurate cross section which has resulted from our new work is in excellent agreement with the cross section calculated theoretically.

(4) Diffusion coefficients from time-of-flight measurements.

Recent work published by another laboratory suggests either that diffusion coefficients measured by lateral diffusion experiments are in error by as much as 50%, or that a difference of this order exists between the longitudinal and lateral diffusion coefficients. The work in helium reported last year appears to refute conclusively the first alternative, while the second seems untenable on theoretical grounds. Experiments were therefore made in this laboratory by a somehhat different technique to check the experimental evidence leading to these suggestions. Our results support the conclusion that in general the diffusion of a plane "pulse" of electrons is not as large as might be expected on the basis of accepted theory. The suggestion has been made that the experimental results may be due to the energy distribution of the electrons being strongly dependent on position. In general, such a dependence would reduce the spread of the pulse and this reduction would normally be interpreted as being due to a smaller diffusion coefficient.

(5) Space charge effects in lateral diffusion experiments.

The experiments at low temperature described in section (2) provided further confirmation of the influence of space charge effects from negative ions formed by electron attachment. In the experiments to measure D/μ at room temperature, approximately 1 part per million of oxygen in hydrogen produces a measurable dependence of the current ratios on the total electron current. At $77^{\circ}K$ a similar dependence was observed with concentrations of the order of a few parts in 10^{10}. These observations were found to be quite consistent with a theory based on the three body attachment of electrons to oxygen. One consequence of these new results is the further confirmation of the sensitivity of this method for measuring attachment rates for thermal electrons in three body collisions. Furthermore, it is clear that this phenomenon could form the basis of a simple method for detecting concentrations of oxygen in a carrier gas with a sensitivity two to three orders of magnitude larger than any known method.

(6) Miscellaneous

As part of the programme to measure and publish standard data for electron and ion transport coefficients, measurements were made of the drift velocity of electrons in carbon dioxide and of potassium ions in hydrogen. A series of measurements of the "magnetic drift velocity" in hydrogen and deuterium is nearing completion.

LIST OF PUBLICATIONS

Crompton, R.S., Liley, B.S., McIntosh, A.I. and Hurst, C.A.‡

"The extension of swarm techniques to the measurement of electron energy for conditions near electrical breakdown".

Proceedings of the Seventh International Conference on Ionization Phenomena in Gases, Belgrade, 1965.

Crompton, R.W., Rees, J.A. and Jory, R.L.

"The diffusion and attachment of electrons in water vapour".

Proceedings of the Seventh International Conference on Ionization Phenomena in Gases, Belgrade, 1965.

Crompton, R.W., Rees, J.A. and Jory, R.L.

"The diffusion and attachment of electrons in water vapour".

Aust. J. Phys. 18, 541, 1965.

Huxley, L.G.H., Crompton, R.W. and Elford, M.T.

"Use of the parameter E/N".

Brit. J. Appl. Phys. 17, 1237, 1966.

Elford, M.T.

"The drift velocity of electrons in carbon dioxide at 293°K."

Aust. J. Phys., 19, 629, 1966.

‡ Not a member of this University.