SHORT COMMUNICATION

A NOTE ON THE LONGITUDINAL DIFFUSION OF ELECTRONS IN ARGON*

By A. G. Robertson† and J. A. Rees‡

It has been shown both experimentally and theoretically that the diffusion of electrons subject to the influence of an applied electric field is often significantly different in directions parallel and normal to the electric field (Wagner, Davis, and Hurst 1967; Parker and Lowke 1969; Lowke and Parker 1969; Skullerud 1969). Lowke and Parker (1969) showed that the ratio of the diffusion coefficients (D_L parallel to the electric field and D_T normal to the field) is particularly sensitive to rapid variations with energy of the momentum transfer cross section of the electrons. It is to be expected therefore that for electrons in argon the Ramsauer–Townsend minimum in the momentum transfer cross section at energies of $\sim 0 \cdot 3$ eV will have a marked influence on the value of D_L.

Previous measurements of D_L for argon by Wagner, Davis, and Hurst (1967) were restricted to values of $E/N \gtrsim 5 \times 10^{-2}$ Td (where 1 townsend $= 10^{-17}$ V cm^2) whereas values of E/N down to $\sim 2 \times 10^{-3}$ Td are required to investigate the influence of the Ramsauer–Townsend minimum. The object of the present investigation was to measure D_L over this range of E/N and to compare the values obtained with those predicted by Lowke and Parker (1969) on the basis of existing momentum transfer cross section data.

Values of D_L were obtained from measurements made using a drift tube which, together with most of the associated vacuum and electrical equipment, has been previously described by Crompton, Elford, and McIntosh (1968) and Crompton and McIntosh (1968). In the present work the electrical shutters were $10 \cdot 00$ cm apart and were operated using square-wave pulses with an amplitude of up to 10 V and a duty cycle, i.e. pulse duration per period, that could be varied between 1 and 10%. Wherever possible, duty cycles of 1, 2, or 3% were employed so as to limit the width of the electron pulses admitted to the drift region through the first shutter. To minimize errors due to possible contact potential differences between the electrodes of the drift tube it was desirable to operate the tube with an electric field between the two shutters of $\gtrsim 1 \cdot 5$ V cm^{-1}. It followed that in order to reach values of $E/N \approx 2 \times 10^{-3}$ Td the experiments were best conducted at gas pressures of near atmospheric pressure and at a temperature of 90 K. Gas pressures of 700 and 800 torr were employed. The argon used for the experiments was Matheson research

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† Ion Diffusion Unit, Research School of Physical Sciences, Australian National University; present address: College of Advanced Education, Wagga Wagga, N.S.W. 2650.

‡ Ion Diffusion Unit, Research School of Physical Sciences, Australian National University, P.O. Box 4, Canberra, A.C.T. 2600; on leave from the University of Liverpool, England.

grade gas, containing less than 5 p.p.m. of impurity, which was further purified by passing the gas samples through a cell containing titanium wire at a temperature of 800°C (Virgil and Gibbons 1955).

The values of D_L were determined as values of D_L/μ, where μ is the electron mobility, and were found by measuring the resolving power $\mathscr{R}$ of the electron pulses transmitted through the drift tube. This quantity is defined as

$$\mathscr{R} = f_0/(f_1-f_2)\,,$$

where f_0 is the frequency at which the current transmitted by the electrical shutters is a maximum and f_1 and f_2 are the frequencies at which the transmitted current is half its maximum value. The resolving power is related to D_L/μ, to a good approximation, through the equation (Lowke 1962; Milloy, to be published)

$$\mathscr{R} = \tfrac{1}{4}\{V/(D_L/\mu)\ln 2\}^{\frac{1}{2}}\,,$$

where V is the total d.c. voltage applied between the two shutters.

The accuracy of the data for D_L/μ is chiefly limited by the accuracy to which the frequency differences f_1-f_2 could be determined; the experimental errors in f_1, f_2, and f_0 were found to be less than $0\cdot25\%$, leading to random errors in D_L/μ of the order of 5%. Errors involved in the measurements of V and of E/N were entirely negligible by comparison with those involved in determining f_1-f_2. In addition to the random errors, the values of D_L/μ are subject to systematic errors as a result of the finite initial width of the electron pulses transmitted by the first shutter. Using duty cycles of between 1 and 4% the observed variation of f_1-f_2 with pulse duration was somewhat less than that expected and was usually within the experimental scatter. The reason for this is not understood. The experimental results shown in Figure 1 are those obtained with the lowest duty cycle used in each case and have not been corrected to allow for the finite initial width of the pulses. The values of D_L/μ should therefore be regarded as upper limits to the true values.

Figure 1 shows the rapid variation of the ratio D_L/μ with E/N over the range of E/N studied, the ratio varying by a factor of seven as E/N increases from 2×10^{-3} to $3\cdot7\times10^{-3}$ Td. A qualitatively similar variation was predicted by Lowke and Parker (1969) who based their calculations on the cross section data derived by Engelhardt and Phelps (1964) from the then available transport data. Lowke and Parker's calculations were made for a temperature of 77 K whereas the present measurements were made at 90 K. However, calculations show that the values of D_L/μ calculated at the two temperatures are almost identical.

Figure 1 also shows the curve we obtained when Lowke and Parker's (1969) analysis was used in conjunction with Golden's (1966) momentum transfer cross section. This cross section, which was derived from measurements of the total cross section, exhibits a Ramsauer minimum that is much narrower and deeper than that derived by Engelhardt and Phelps (1964). Notwithstanding the discrepancies between the experimental curve and each of the calculated curves, it can be seen that the main features of the curves predicted by Lowke and Parker's analysis are confirmed by experiment.

In the vicinity of the maximum at $E/N \approx 3{\cdot}7\times10^{-3}$ Td the experimental values are significantly smaller than the values calculated using either cross section. When assessing the significance of the disparity it should be remembered that the experimental values are, in fact, upper limits to the true values. It appears, therefore, either that both cross sections may be appreciably in error at or below energies of about 1 eV or that Parker and Lowke's (1969) theory may require refinement when there is a rapid variation of the momentum transfer cross section with energy.

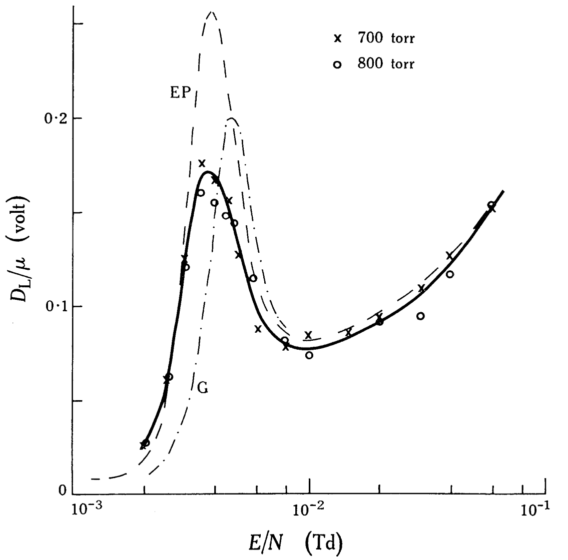

Fig. 1.—Ratio D_L/μ for electrons in argon at 90 K. The bold curve shows the present experimental result. The other curves have been calculated (see text) from the cross sections of:
EP, Engelhardt and Phelps (1964);
G, Golden (1966).

Acknowledgments

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