Journal of Physics D: Applied Physics

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To cite this article: W Roznerski and K Leja 1980 *J. Phys. D: Appl. Phys.* **13** L181

J. Phys. D: Appl. Phys., 13 (1980) L181–4. Printed in Great Britain

LETTER TO THE EDITOR

The ratio of lateral diffusion coefficient to mobility for electrons in hydrogen and nitrogen at moderate E/N

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Received 30 July 1980

Abstract. With the help of the Townsend and Huxley technique the measurement of the ratio of lateral diffusion coefficient to mobility D/μ in hydrogen and nitrogen at ambient temperature has been carried out for reduced electric fields $34{\cdot}7 \leqslant E/N \leqslant 462{\cdot}7$ Td and $2{\cdot}5 \leqslant E/N \leqslant 404{\cdot}6$ Td respectively.

The present work contains the results of the measurement of the coefficient D/μ in hydrogen and nitrogen performed by means of the Townsend and Huxley method (Huxley and Crompton 1974) in which thermal electrons emitted from a point source diffuse through a gas in a homogeneous electric field and are finally collected by an anode. The method depends on the measurement of the ratios of the currents arriving at the coaxial segments of a divided anode.

The steady-state solution of the electron transport equation electron density was given for the first time by Warren and Parker (1962) assuming isotropic diffusion and by Lowke (1973) for anisotropic diffusion. In the presence of attachment and ionisation processes the electron density, expressed as an infinite series of dipole solutions, has the form given by Roznerski and Mechlińska-Drewko (1979).

The fraction R of the total current arriving at the central disc of a divided anode, obtained by integrating the current density over the respective ring-shaped areas, is given by

$$\begin{aligned} R = & \sum_{k=-\infty}^{+\infty} [\![r'_k{}^{-3} \exp[\lambda_L h - \beta r'_k]\{(2k-1)^2 h^2(\beta r'_k + 1) - [1 - \lambda_L h(2k-1)] r'_k{}^2\} \\ & - [\beta + \lambda_L \operatorname{sgn}(2k-1)] \exp[h(\lambda_L - \beta|2k-1|)]]\!] \\ & \times \sum_{k=-\infty}^{+\infty} [\![r''_k{}^{-3} \exp[\lambda_L h - \beta r''_k]\{(2k-1)^2 h^2(\beta r''_k + 1) - [1 - \lambda_L h(2k-1)] r''_k{}^2\} \\ & - [\beta + \lambda_L \operatorname{sgn}(2k-1)] \exp[h(\lambda_L - \beta|2k-1|)]]\!]^{-1} \end{aligned} \qquad (1)$$

where

$$r'_k = [(2k-1)^2 h^2 + (D_L/D) b^2]^{1/2} \qquad r''_k = [(2k-1)^2 h^2 + (D_L/D) c^2]^{1/2}$$
$$\beta = \lambda_L[1 - (2\alpha/\lambda_L)]^{1/2} \qquad \lambda_L = W/2D_L.$$

In these equations b, c, h, α, W, D and D_L are the radius of the central disc, the outer radius of the anode, the length of the diffusion space, the ionisation coefficient, the drift velocity, and the lateral and longitudinal diffusion coefficients respectively.

0022-3727/80/100181+04 $01.50

The apparatus used in this experiment, constructed to ultra-high-vacuum standard, has been described previously (Roznerski and Mechlińska-Drewko 1977).

The measurements of gas pressure were made with two mercury-filled McLeod gauges which covered the range of pressure 0·1–9 Torr with an accuracy better than ±1% for all pressures. Spectrally pure hydrogen and nitrogen of purity higher than 99·99% were used in these experiments.

The values of the α and D_L/μ coefficients have been taken from previously published data. The α values for hydrogen over the whole range of E/N have been adopted from the data of Rose (1956), and for nitrogen from Daniel and Harris (1970) for $E/N < 170$ Td, from Heylen (1959) for $170 < E/N < 250$ Td and from Jones (1968) for $E/N > 250$ Td. The D_L/μ values in hydrogen have been taken from the measurements by Blevin *et*

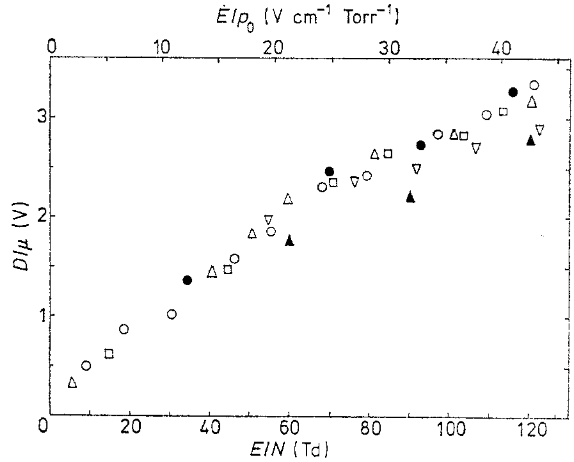

Figure 1. D/μ as a function of E/N in hydrogen below 125 Td. ●, present results; ○, Roznerski (1978); △, Blevin *et al* (1978a); ▲, Blevin *et al* (1978b); ▽, Crompton *et al* (1965); □ Kontoleon *et al* (1972).

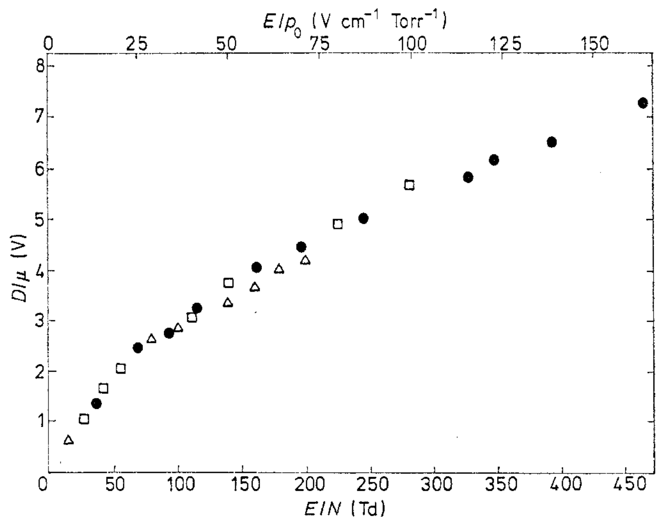

Figure 2. D/μ in hydrogen at moderate E/N. ●, present results; △, Blevin *et al* (1978a); □, Saelee and Lucas (1977).

al (1978a) for $E/N \leqslant 180$ Td, and from work by Lowke and Parker (1969) in nitrogen for $E/N \leqslant 200$ Td. For $E/N > 180$ Td in hydrogen and > 200 Td in nitrogen the values of D_L/μ have been estimated on the basis of classical theory of collisions and the thermodynamic treatment of anisotropic diffusion in an electric field (Robson 1972).

The estimated total uncertainty of D/μ does not exceed $\pm 5\%$ for both hydrogen and nitrogen over the whole range of E/N.

The results for hydrogen are presented in figures 1 and 2. Below 100 Td there is good agreement with the results of Blevin *et al* (1978a), obtained from current ratio measurements, and Kontoleon *et al* (1972). For $E/N > 100$ Td the present data points are a few per cent higher than those quoted above. However they agree very well with the data presented by Saelee and Lucas (1977). For $60 < E/N < 150$ Td discrepancies of up to 15–20% have been noticed between our results and those of Blevin *et al* (1978b),

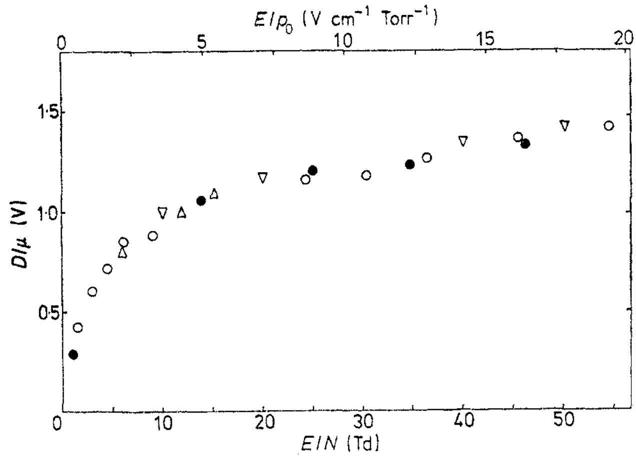

Figure 3. D/μ as a function of E/N in nitrogen below 55 Td. ●, Present results; ○, Roznerski (1978); ▽, Engelhardt *et al* (1964) at 77 K; △, Jory (1965).

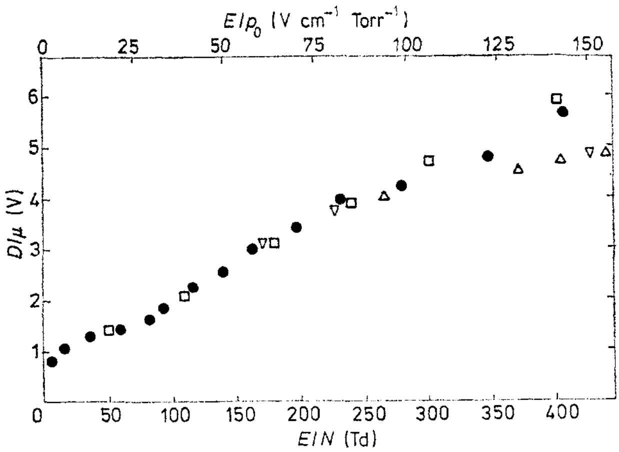

Figure 4. D/μ in nitrogen at moderate E/N. ●, Present results; □, Engelhardt *et al* (1964) at 77 K; △, Fletcher and Blevin (1979); ▽, Kontoleon *et al* (1973).

which were obtained from observations of the photon flux produced in a Townsend discharge.

Our results in nitrogen are illustrated in figures 3 and 4. Over the range $2{\cdot}5 \leqslant E/N < 55$ Td (figure 3) the agreement between our results and those of Engelhardt *et al* (1964) and Jory (1965) is good. For $150 < E/N < 300$ Td (figure 4) there is excellent agreement with the results by Kontoleon *et al* (1973), but for $E/N > 300$ Td our results are higher than those of Kontoleon *et al* (1973), and Fletcher and Blevin (1979). Over the whole E/N range the agreement between our results and the data of Engelhardt *et al* (1964) is satisfactory.

The authors would like to thank Dr J Fletcher for forwarding detailed data used in the preparation of this paper. This work was supported in part by the Institute of Experimental Physics of Warsaw University.

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