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ELECTRON TRANSPORT COEFFICIENTS IN GASEOUS PARAHYDROGEN

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Measurements of the drift velocity and the ratio of diffusion coefficient to mobility have been made for electrons in parahydrogen at 77°K. The differences in the transport coefficients in normal hydrogen and parahydrogen demonstrate the influence of the difference in the statistical weights of the rotational levels in the two gases.

For many years measurements of the transport coefficients for a swarm of electrons drifting and diffusing through a gas under the influence of an electric field have been used to estimate the energy dependence of the cross section for the collisions between the electrons and the gas molecules.[1] More recently, modern high-speed computers have enabled the true energy dependence of both elastic and inelastic cross sections to be inferred from these data.[2] Although considerable success has been achieved in the inert gases at energies well below the first excitation threshold,[3,4] the results obtained in the molecular gases have been less satisfactory. Both the spread in some of the experimental data and the difficulties in finding a unique set of cross sections have contributed to the ambiguity of the results obtained.

Techniques for the accurate measurement of the electron drift velocity, W, at 77°K have been described previously.[5] The additional difficulties in measuring the ratio of diffusion coefficient to mobility, D/μ, at the same temperature have now been overcome so that both transport coefficients can be measured with an error of less than ±2% over an extended range of E/N at 77°K (here E is the electric field strength and N the gas number density). The accuracy of these data largely overcomes the first of the difficulties in determining the cross sections but there remains the more fundamental problem of deducing the cross sections for a number of processes from the measured values of only two transport coefficients. However experiments in pure parahydrogen at 77°K should make it possible to determine a unique cross section for rotational excitation since, in this special case, only the cross sections for momentum transfer and for one rotational transition need to be taken into account.

The measurements of W in pure parahydrogen at 77°K were made using the Bradbury-Nielsen time-of-flight technique,[5] while the measurements of D/μ were made using the Townsend-Huxley lateral-diffusion method.[6] In both sets of experiments the hydrogen used was of the same purity as that used earlier[5,6] and was shown to contain at least 98% of the parahydrogen form. Most of the other experimental techniques were essentially similar to those described elsewhere.[5,7] However, since the hot platinum filament used as an electron source in the earlier experiments caused rapid conversion of the parahydrogen to the 75%-orthohydrogen, 25%-parahydrogen mixture, it was replaced

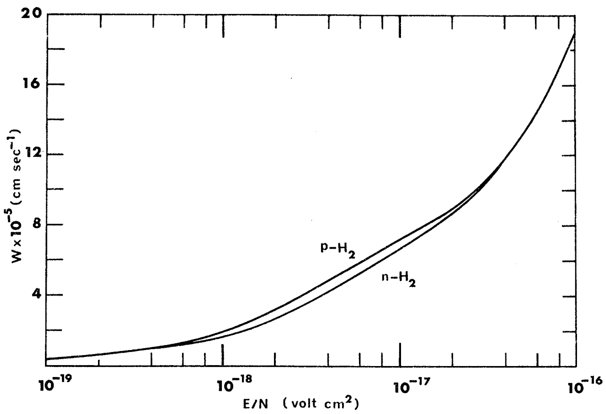

FIG. 1. Comparison of electron drift velocities in normal hydrogen and parahydrogen at 77°K.

by a silver-coated foil of americium-241 which generated electrons by volume ionization of the gas. In both the W and D/μ experiments the values of E/N were found from the known values of the electric field strength E and accurate measurements of the gas temperature and pressure. A complete description of the experimental techniques will be given elsewhere.

There have been no previous measurements of electron transport coefficients in parahydrogen. Comparisons of the present values of W and D/μ with similar data taken in normal hydrogen are shown in Figs. 1 and 2. The values of D/μ in normal hydrogen were obtained during the present investigation while the corresponding drift velocities were obtained earlier by Lowke.[5] The accuracy of the data is sufficient to show the small differences in the transport coefficients which result from the differences in the statistical weights of the rotational levels in the two gases.[8] At low values of E/N the electrons are almost in thermal equilibrium with the gas molecules, and the values of W and D/μ are therefore the same in both gases. As the value of E/N is increased, the electrons obtain sufficient energy to cause rotational excitation of the molecules; the differences in the statistical weights of the rotational levels in normal hydrogen and parahydrogen cause the curves to diverge as shown. When the mean electron energy approaches 0.5 eV, the majority of the electrons in the swarm have sufficient energy to cause vibrational excitation. Because the cross section for vibrational excitation is so much larger than those for rotational excitation[9] and is the same for both gases, the differences in the

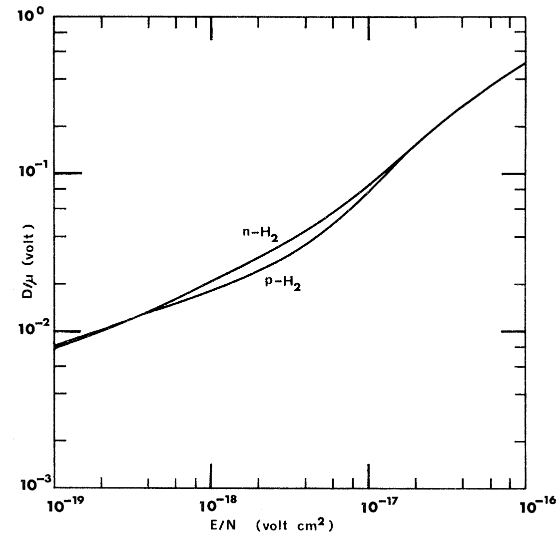

FIG. 2. Comparison of values of D/μ in normal hydrogen and parahydrogen at 77°K.

rotational levels become unimportant and the two curves merge again.

Various theoretical forms of the cross section for rotational excitation[8,10,11] are being examined to see which of them is consistent with the present experimental data.

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