Scattering of Low-Energy Electrons by Atomic Hydrogen

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The total cross section for the scattering of electrons by atomic hydrogen has been measured as a function of electron energy from 3.1 to 12.3 ev. The basic measurement compared the number of electrons scattered from a region defined by the intersection of an electron beam and a chopped molecular beam with the number scattered when the hydrogen beam was partially dissociated. By measuring the degree of dissociation with a mass spectrometer, one may obtain the ratio of cross sections of atomic and molecular hydrogen for a given energy. The absolute atomic values were calculated from these ratios and molecular hydrogen values obtained from the literature. In the experiment most of the scattered electrons were detected (the angular resolution was about 25°), thereby differing from a previous measurement by Brackmann, Fite, and Neynaber. Our results are in good agreement with several theoretical estimates, e.g., that of McEachran and Fraser.

I. INTRODUCTION

THE development of the modulated molecular beam technique has recently stimulated experimental and theoretical investigations of the elastic scattering of slow electrons by atomic hydrogen. As a basic three-body interaction this problem has considerable interest. In a previous experiment, Brackmann, Fite, and Neynaber[1] (BFN) measured electrons scattered by atomic hydrogen into a cone whose axis was normal to the initial electron direction. About 10% of the total number of scattered electrons were collected. The measurements were projected into total collision cross sections by the use of a theoretical angular distribution obtained by Bransden, Dalgarno, John, and Seaton[2] (BDJS). These total cross sections, although they did not allow distinction between several theoretical estimates, were consistent with theoretical predictions.

Because our experiment was designed to collect most of the scattered electrons, total cross sections were obtained directly from the measurements. Further, the present experiment is sensitive enough, particularly at the higher energies, to distinguish between the BDJS theoretical results and several more recent treatments.

II. EXPERIMENTAL

The apparatus, experimental procedure, and calculation of results were similar to those of our previous investigation of the atomic oxygen[3] cross section. The only experimental changes were in the source. The hydrogen (Liquid Carbonic, 99.8% pure) was used directly from a cylinder. The rf discharge, characterized by a deep red glow, was operated at about 0.8 mm Hg pressure. Typically, 30% of the molecules dissociated. While the temperature of oxygen remained essentially constant in the discharge,[3] that of hydrogen rose about 50°C. A cooling jacket was installed around the discharge tube. A flow of cold air through this jacket was adjusted to cool the discharge to room temperature. The temperature was measured by the krypton additive method previously described[3] and by a thermocouple. The temperatures obtained by these two methods were in agreement. Some measurements were made without cooling. Temperature corrections were made to these measurements. The results were within experimental error of those obtained by the cooling method.

The atomic cross sections were calculated from the data and from the molecular hydrogen cross sections. The latter were obtained from an arithmetic average of the results of Brüche[4] and Normand.[5] In the energy range considered, their results do not differ by more than 5% from this mean.

As in the oxygen experiment, a correction was needed because the Knudsen condition at the source exit was

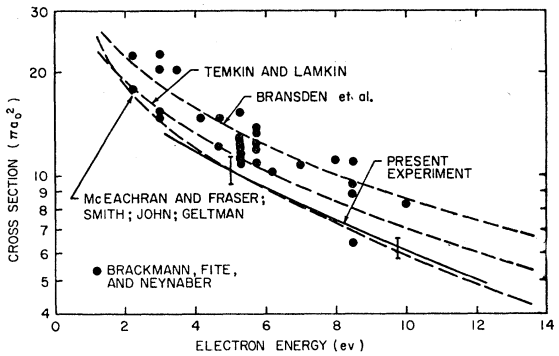

FIG. 1. Total collision cross sections for electrons scattered by atomic hydrogen. The BFN points are shown as originally published and were obtained from the p-wave calculations of BDJS as well as experimental measurements. In the energy range from 3.1 to 7.24 ev, half of the present experimental points lie within a ±9% range of the curve. From 7.25 to 12.3 ev, half of the points are within ±6%. These limits are shown as brackets on the experimental curve.

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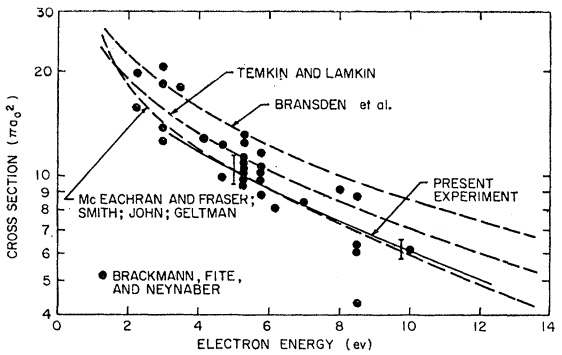

FIG. 2. Total collision cross sections for electrons scattered by atomic hydrogen. The BFN points were obtained from the p-wave calculations of McEachran and Fraser and experimental measurements. The BFN cross sections now appear to be consistent with our results.

not entirely satisfied. The correction (about minus 4%) was determined by an ionization experiment, which has been previously described.[3]

III. DISCUSSION OF RESULTS

A least squares fit of our data is given in Fig. 1. Also shown are the results of the BFN experiment and several theoretical calculations. Our results are in good agreement with the lowest theoretical curve. This is best seen at the higher energies. In the energy range from 3.1 to 7.24 ev, one-half of the experimental points lie within a $\pm 9\%$ range of the curve. From 7.25 to 12.3 ev, one-half of the points are within $\pm 6\%$.

Bransden, Dalgarno, John, and Seaton[2] employed a variational calculation containing both s- and p-wave scattering. Temkin and Lamkin[6] calculated s-, p-, and d-wave scattering by the method of polarized orbitals.

McEachran and Fraser,[7] Smith,[8] and John[9] employed numerical methods with exchange approximations to obtain the scattering. Geltman[10] used a variational method in which a trial function allowed for the virtual excitation of the $2s$ and $3s$ states.

Only three theoretical curves appear in Fig. 1. The lowest one represents the work of McEachran and Fraser. The cross sections predicted by John lie on the same curve, while those obtained by Geltman are only slightly higher ($<5\%$). Smith has calculated 2 points (at 11.0 and 13.6 ev) which also are close to the lowest curve.

The BFN total cross sections are shown in Fig. 1 as originally published, but it must be remembered that they were obtained from the p-wave calculations of BDJS as well as experimental measurements. Subsequently, an angular distribution experiment of Gilbody, Stebbings, and Fite[11] indicated somewhat smaller p-wave contributions such as those predicted by McEachran and Fraser, John, and Geltman. We have recomputed the total cross sections by using the BFN measurements, and the McEachran and Fraser p-wave results in the formula given by BFN. The results are shown in Fig. 2. It is seen that the BFN cross sections now appear to be consistent with our results.

The present results, particularly at the higher energies, appear to support the lowest theoretical curve.

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