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# ELECTRON SPIN POLARIZATION BY ELECTRON-MOLECULE COLLISIONS*

W. Hilgner and J. Kessler†
Physikalisches Institut der Technischen Hochschule Karlsruhe, Karlsruhe, Germany
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A great deal of our present knowledge of molecules has been obtained by electron-scattering experiments. So far, only scattering intensities were observed in these experiments; one measured the angular distribution of the scattered intensity or its energy dependence, and from these data one could draw conclusions about the structure of the scattering centers.

It is the aim of the present paper to demonstrate that information independent of the scattered intensity can be obtained from experiments of this kind. Electrons scattered by molecules can have an appreciable spin polarization giving additional information about the scattering center which cannot be obtained by intensity measurements. [The spin polarization $P$ of an electron beam is defined as $(N_\uparrow - N_\downarrow)/(N_\uparrow + N_\downarrow)$, where $N_\uparrow$ and $N_\downarrow$ are the numbers of electrons with spin parallel and antiparallel to the direction of quantization which in our case is given by the normal to the scattering plane.]

Figure 1 shows the polarization (points with statistical error) of 300-eV electrons scattered elastically by $C_2H_5I$ and $I_2$ at scattering angles between 30 and 150°. Similar measurements have been made at other electron energies and with other molecules; they will be published elsewhere. The experimental method is very similar to that which has been fully described in a previous paper[1] and can be outlined as follows:

A beam of monoenergetic electrons crosses a molecular beam by which some of the electrons are scattered. The scattering angle $\theta$ could be varied between 0 and 150°; the angular resolution was 1°. The scattered electrons first pass through an energy filter lens which removes inelastically scattered electrons. They are then post-accelerated to 120 keV and enter a Mott detector in which their polarization is analyzed. For the measurement of the differential cross sections, which are also represented in Fig. 1, the scattered intensity was recorded instead.

The polarization effects shown in Fig. 1 are very similar to those found earlier with mer-

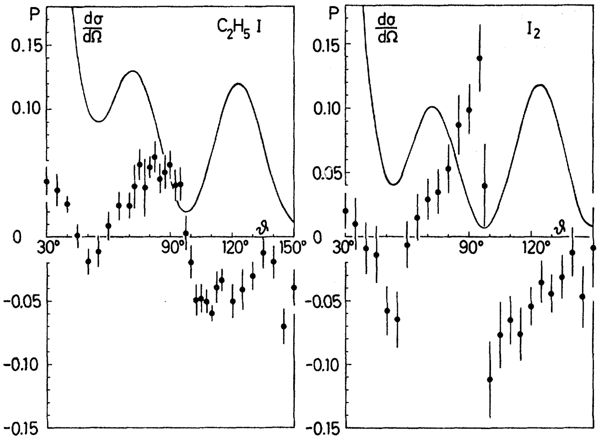

FIG. 1. Polarization (points with statistical errors) and differential cross section (arbitrary units) versus scattering angle $\theta$ for 300-eV electrons scattered by $C_2H_5I$ and $I_2$.

cury atoms.[2,1] The polarization curve $P(\theta)$ has an oscillating character with a positive and a negative peak near the deep minimum of the cross section.

It is interesting to compare the polarization curve from $C_2H_5I$ with that from the iodine molecule. The structure of this curve is the same in both cases; minima and maxima are at the same angles, but their values are higher in the case of $I_2$. We know from other measurements we have made that electrons scattered by atoms with a low atomic number (like H and C) are virtually unpolarized (the spin-orbit coupling which is responsible for the polarization effect is very small there). So, we can consider the scattered electron wave in the case of $C_2H_5I$ as being composed of two parts: One part comes from the iodine atom and is marked by its polarization; this polarization is "diluted" by the unpolarized part coming from the C and H atoms. Comparing the polarization in the case of $C_2H_5I$ with that of the iodine provides a means of solving, in this example, the old problem in slow-electron scattering[3] of telling how much of the scattered intensity comes from one part of the molecule and how much comes from another part.

Generally speaking, the polarization is given by[4]

$$P=i\frac{FG^*-F^*G}{|F|^2+|G|^2},$$

where the complex functions $F$ and $G$ are obtained by coherent superposition of the amplitudes scattered by the single atoms of the molecule, provided that the independent-atom model (free atoms in the geometrical arrangement of the molecule) holds. This formula shows that measurements of the polarization yield information on the complex scattering amplitudes $F$ and $G$ which is different from that obtained by a measurement of the cross section $d\sigma/d\Omega=|F|^2+|G|^2$. Therefore, measurements of the polarization give insight into the molecular structure which is independent of that obtained by the measurements of scattered intensities made up to now.

For a quantitative analysis of molecules by means of experimental polarization curves one needs as a first step the scattering amplitudes of the single atoms calculated on the basis of Dirac's equation. Calculations of that kind are feasible nowadays as the results of Holzwarth and Meister[5] as well as Bunyan and Schonfelder[6] show, and they are of great accuracy.[1] Calculations for the other elements are highly desirable.

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†Visiting Professor at Department of Physics, Stanford University, Stanford, California.

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