Elastic Small-Angle Electron Scattering by He, Ne, and Ar at 35 keV

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New experimental data are presented for the scattering of 35-keV electrons by He, Ne, and Ar in the limit of vanishing momentum transfer. Previous data of Geiger and Morón-León show a strong forward peak with structures similar to a Fraunhofer diffraction pattern (shadow scattering) for elastic scattering of 15–25-keV electrons. No recent theory can explain this effect; therefore we repeated the experiment. The new data agree well with partial-wave calculations utilizing configuration interaction and Hartree-Fock potentials. The results are compared with the previous unexpected findings.

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Geiger and Morón-León have reported experimental observations of a strong forward peak in the cross section for elastic scattering of 15–25-keV electrons by rare-gas atoms.[1] Their data exhibit structures resembling Fraunhofer diffraction patterns. Such interference patterns would require that each atom represent a black disk of 30–50-Å diam in the path of the electrons (shadow scattering). This surprising result required confirmation by a diffraction unit of different design. The new experimental results presented here concern the scattering of 35-keV electrons by He, Ne, and Ar in the limit of vanishing momentum transfer. The data disagree with those of Geiger and Morón-León and agree very well with numerical results based on relativistic partial-wave treatment and relativistic Hartree-Fock potentials.[2] All charge-cloud polarization effects have been neglected in these calculations. No indication of shadow scattering could be found.

The present experimental setup and procedure differ significantly from the previous ones.[3] The most important difference is reflected in a series of three measurements in determination of differential cross sections. These are "main beam" when the target gas beam is turned on, "rest gas" where the residual or escaped target-gas atom distributions in the vacuum chamber are simulated by injection of gas through a port in the chamber wall, and finally "background" where all gas in the system is turned off. Another important difference is the use of a Möllenstedt energy analyzer. The target gas is injected as a vertical beam from a platinum hypodermic needle. Plastic scintillators coupled to photomultipliers are used as detectors of the scattered electrons. The electron beam with an energy of 35 keV is formed by a Steigerwald Telefocus Gun.[4] One other significant feature of the present apparatus is its ability to measure the differential cross sections to large angles for the purpose of matching the relative results to theory in an angular range generally considered safe from distortion by charge-cloud polarization effects.

The Möllenstedt electron-energy analyzer is essentially a cylindrical electrostatic Einzel lens of such a strong power that it leads to very high chromatic aberration for off-axis rays, causing dispersion of the electrons according to their energies.[3,5] By our sweeping of a biasing voltage on the rods forming the lens, energy-loss (E loss) spectra are obtained (Fig. 1) which can be taken for any angle and any projectile energy desired. The experiment is carried out by our either setting the detector slits on the elastic line and using high-speed (detecting and monitoring) counters controlled by a microcomputer, or taking an entire spectrum with a multichannel analyzer for each angle. For highest accuracy the electron energy distributions are first analyzed at small and large angles on either side of zero angle to assure that the system is well aligned and symmetric, and to find the smallest acceptable angles. The differential cross sections are measured while we monitor the electron and gas beam in-

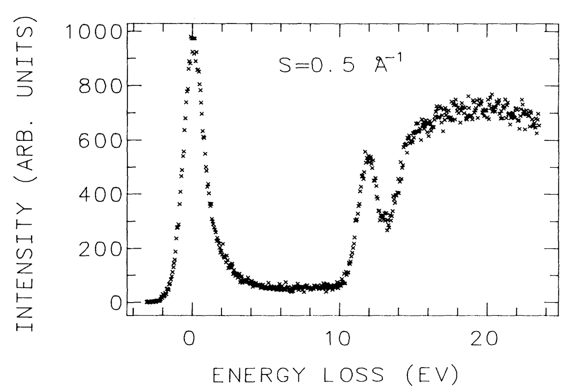

FIG. 1. Energy-loss spectrum for argon.

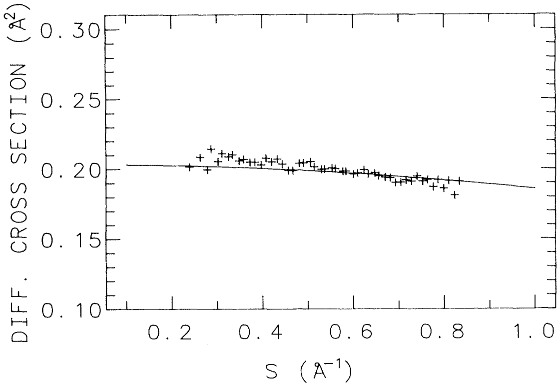

FIG. 2. Small-angle differential cross section for helium. Plusses, experiment; curve, configuration-interaction theory.

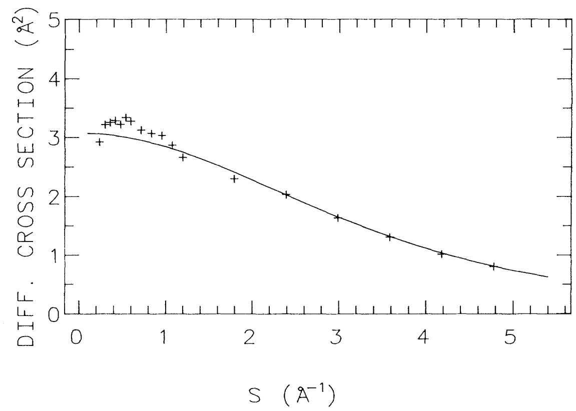

FIG. 3. Small-angle differential cross section for neon. Plusses, experiment; curve, Hartree-Fock theory.

tensities. Finally, the E-loss spectra is rechecked after each run has been completed as a stability check. E-loss spectra are taken for main beam, rest gas, and background measurements which helps to test further the stability of the experiment.

Additional exploratory experiments have been carried out at 30 and 25 keV with the same resulting differential cross sections and E-loss spectra, still lacking the forward peak and any oscillating features.

For helium (Fig. 2) a gentle decrease is found of about 20% between 0.2 and 0.8 Å^{-1}, in excellent agreement with the partial-wave calculations. Similarly, neon and argon (Figs. 3 and 4) cross sections show a slight monotonic decrease. The experiment has been run both with and without a beam stop. Data acquired by these two methods were identical except that when we used a beam stop the small-angle limit was due to the scattering volume being blocked from the detector while when no beam stop was used the limit was determined by the finite size of the unscattered electron beam. The structures in Figs. 2–4 are due to gas pressure fluctuations.

A comparison of the new data and the results of Geiger and Morón-León shows a marked difference in the measured cross sections. The shadow scattering found in the previous experiment[1] could not be confirmed. The new data agree very well with calculated partial-wave cross sections for He, Ne, and Ar. No oscillatory structure in the cross sections has been seen. The small forward peak predicted by theory is not within the angular reach of the present apparatus.[6,7]

A detailed comparison of both experiments and technical methods provides some hints as to where this discrepancy might have its origin. It is mentioned in the final conclusion of Nesbet's study that "excited states in the scattering chamber could be responsible"; an extension of this thought leads to ions. The Rutherford cross sections are extremely forward peaked and as low as 0.2% ion contamination could generate similar forward peaks. Another possibility lies with the insufficient evacuation of the target gas which escapes through the apertures in the target chamber walls. The residual gas above the scattering volume can modify the electron beam by ion filamentation and thus the subtraction of the background signal is distorted. Or if too much residual gas accumulates between the filter lens and the photographic plate then scattering processes in this area again can generate a large forward peak, which has the spatial form of the inelastic cross section, in qualitative agreement with the formerly reported results. None of these arguments, however, can explain the oscillatory behavior of the previous cross sections.

We are aware of the ambiguities of the above listed arguments as it is very hard to judge an experiment without hands-on experience. Therefore these issues should be considered as points of discussion worthy of further investigation in bringing these new data in ac-

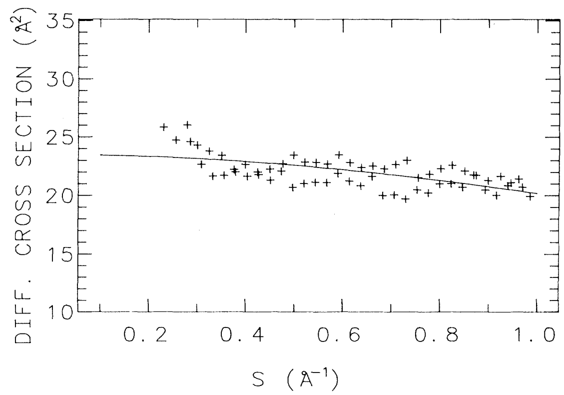

FIG. 4. Small-angle differential cross section for argon. Plusses, experiment; curve, Hartree-Fock theory.

cord with the previous ones.

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