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OBSERVATION OF AUTOIONIZATION LEVELS IN He BY POSITIVE ION BOMBARDMENT*

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Certain highly excited energy levels in helium have been observed optically[1] and by inelastic electron scattering,[2] and have been calculated theoretically.[3] Reported here is the observation of these levels by the measurement of the energy spectrum of electrons emitted after bombardment with protons and hydrogen molecular ions. Some of the states show up clearly by this method which are weak or absent in the other techniques. Berry[4] has previously observed autoionization of helium by this method, but his measurements lacked the resolution necessary to identify the states.

The apparatus consisted of a collision chamber with a parallel-plate electrostatic analyzer and an electron multiplier detector. Individual electrons were counted. The equipment was designed to make measurements of the angular and energy dependence of the cross sections for ejection of electrons from gases by positive ions and is similar to one described previously.[5] Magnetically selected protons or molecular ions from the Concordia Cockroft-Walton accelerator were the bombarding particles. The analyzer was calibrated by making careful measurements with an electron gun source and from the same data the resolution of the analyzer was also determined. The shape of the resolution curve was nearly triangular with a full width at half maximum of about 3%. The electrons were decelerated by 20 volts before entering the analyzer during the measurements with the ion beam, resulting in a resolution which varied from 0.36 eV at 32 eV to 0.66 eV at 42 eV.

The observed energy spectrum consists of a continuous background due to "ordinary" collisional excitation, with a superimposed "line" spectrum due to the autoionizing states. Electrons ejected in a direction nearly opposite that of the ion beam (160°) were used in these measurements since the ordinary cross section is smallest there and the lines stand out most prominently. The lines were still visible, however, at other angles. The helium pressure in the collision chamber was about 1.6 microns for the molecular ion data and about 2.8 microns for the proton data. The bombarding energy in both cases was 75 keV although the states have been observed at ion energies from 25 keV to 250 keV. While no systematic determination of the dependence of the line intensities on ion energy has been made, it appears that the lines become less prominent as the energy is increased above 75 keV.

The energy spectra are shown in Figs. 1 and 2. The energy of the ejected electrons differs from the excitation energy by the ionization potential of the gas, in this case 24.6 eV. The values of the energy levels and their designations as calculated by Burke, McVicar, and Smith[3] are marked in Fig. 1. The levels at 57.8, 58.3, 60.1, and 62.9 eV are in good agreement with the theoretical values. At higher energies the peaks are not as clearly defined and, because the uncertainty due to statistical fluctuations is about as great as some of the peaks, the lines were not

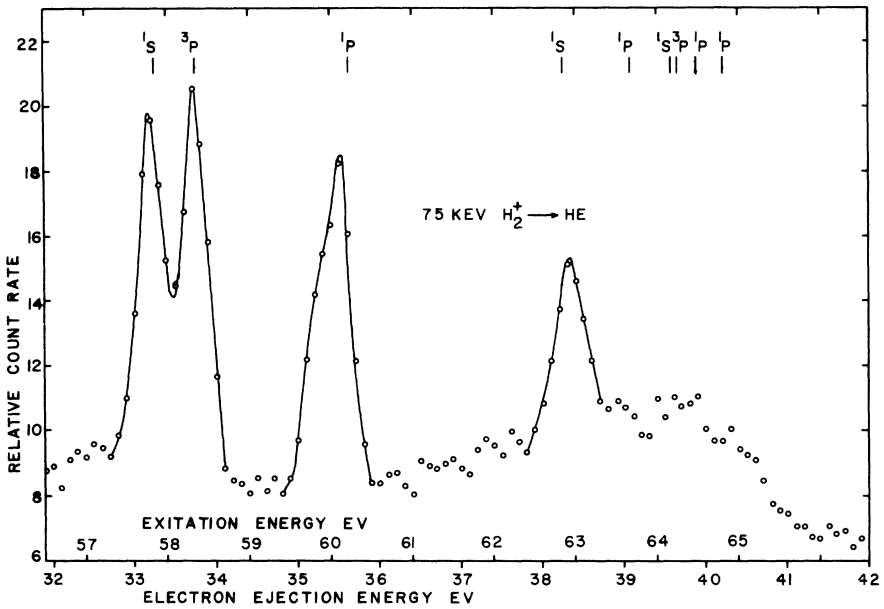

FIG. 1. Counting rate in arbitrary units vs ejected electron energy for 75-keV hydrogen molecular ions incident on helium gas.

drawn in. However, there appear to be small peaks associated with most of the higher energy theoretical values also. Additional small peaks at 61.9 and 62.2 eV were fairly reproducible.

As seen in Fig. 2 the 58.3-eV level is not excited by proton bombardment although it is strongly excited by hydrogen molecular ions. This level is only very weakly excited in the electron scattering work.[2] Likewise, the 62.9-eV level is much more prominent with the molecular beam than with either protons or electrons. In Fig. 1 the widening of the 60.1-eV peak on the low energy side may be due to excitation of ^1D level at 60.0 eV reported by Simpson, Mielczarek, and Cooper.[2]

Using the molecular beam, the 18- to 20-eV

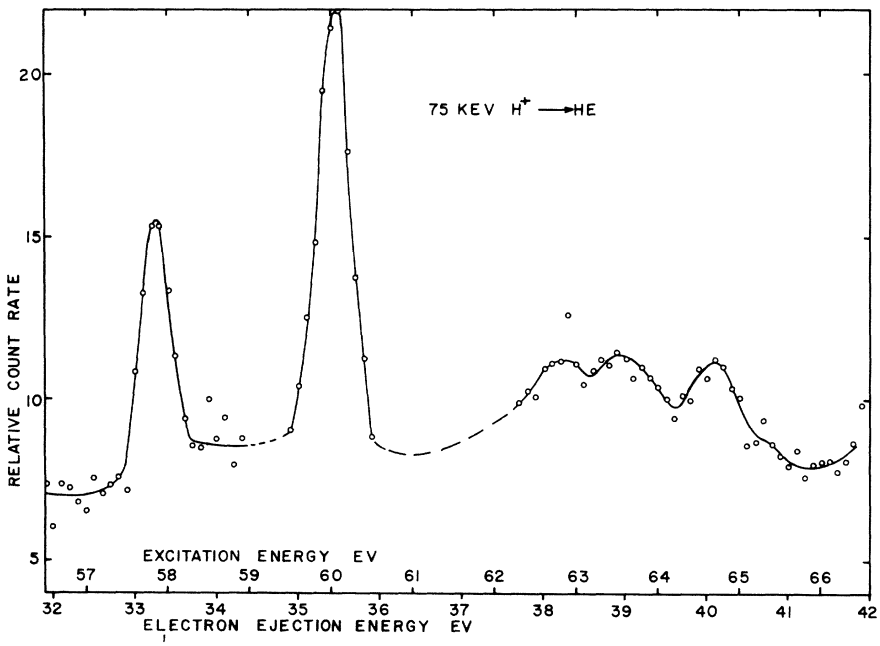

FIG. 2. Counting rate in arbitrary units vs ejected electron energy for 75-keV protons incident on helium gas.

region has also been searched for possible evidence of the resonance observed by Schulz[6] using electron scattering. At best only a very small peak was observed, hardly distinguishable above the statistical variations in the counting rate. Additional work is planned using other gases.

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INVESTIGATION OF ABSORPTION EFFECTS IN THE REACTION $\pi^- + p \to \pi^- + \pi^0 + p$ AT 4 GeV/c *†

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The importance of absorptive effects on production amplitudes for peripheral scattering at high energies has been considered recently by several authors.[1-4] We wish to report the results of an analysis of absorptive effects in a study of 390 events of the type

$$\pi^- + p \to \pi^- + \pi^0 + p \qquad (1)$$

at 4 GeV/c obtained by the German-British Collaboration at CERN.[5]

We selected 133 events of the type

$$\pi^- + p \to \rho^- + p, \qquad (2)$$

with π^-, π^0 effective mass between 0.6 and 0.9 GeV. It has been shown[5] that the ρ^- is produced peripherally in this reaction, with a cross section of 0.45 ± 0.08 mb. Since this is a very small fraction of the total cross section, it is reasonable to expect absorption effects in the initial and final states of Reaction (2), with competing open channels tending to reduce the low partial-wave amplitudes below the values given by the simple peripheral model. If no appreciable cancellation between competitive inelastic channels occurs,[6] it should be possible to investigate the absorption effects experimentally.

Ross and Shaw,[1] using a distorted-wave Born approximation, have predicted that the initial- and final-state interactions in events of type (2) should lead to demonstrable shifts in position and width of the ρ peak with increasing four-momentum transfer. We see no evidence for such shifts in these data; however, the limited statistics might well permit such effects to go undetected.

Durand and Chiu[2] have used a modified distorted-wave Born approximation including the rather significant spin dependence of the reaction to calculate the effect of absorption terms on the differential cross section for Reaction (2). Their prediction is compared with experiment in Fig. 1, in which the dependence of cross section on momentum transfer is shown by the distribution of the proton c.m.-system angle. For the curve labeled $\langle\pi\rangle$ the coupling constants were taken as $g_{\pi NN}^2/4\pi = 14.5$ and $g_{\pi\pi\rho}^2/4\pi = 2.2$,[7] and

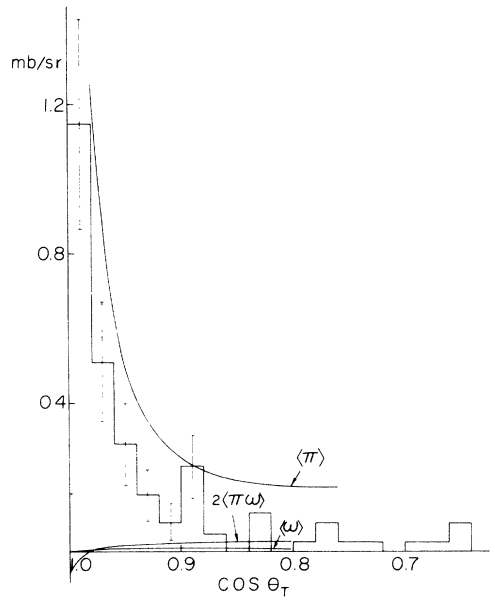

FIG. 1. Differential cross section for the reaction $\pi^- + p \to \rho^- + p$ near the forward direction. The theoretical curves calculated from the model of Durand and Chiu for one-pion exchange $\langle\pi\rangle$, for one-omega exchange $\langle\omega\rangle$, and the interference term $2\langle\pi\omega\rangle$ are shown for comparison.