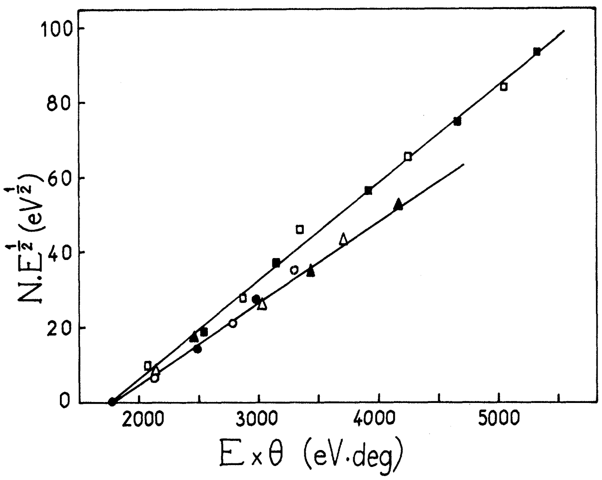

FIG. 3. The quantity $NE^{1/2}$ is plotted as a function of $\tau = E\theta$. N is the index number for the extrema of $n(\tau)$ ($N = 0, 1, 2, \cdots$ for maxima; $\frac{1}{2}, \frac{3}{2}, \cdots$ for minima). Open symbols are maxima, closed are minima: circles, 200 eV; triangles, 300 eV; squares, 350 eV.

where μ is the reduced mass and b_1 and b_2 are the values of the impact parameter b corresponding to the two scattering potentials for a given scattering angle θ. The linear dependence of $NE^{1/2}$ on τ shows that Δb is approximately independent of τ: $\Delta b \simeq 0.62$ a.u. At 350 eV, the behavior of the differential cross section is more complicated: Oscillations appear also in this case, but they seem to be distorted by another phenomenon. In this case the quantity $NE^{1/2}$ is still a linear function of $\tau - \tau_0$ (see Fig. 3), but the slope $\partial(NE^{1/2})/\partial\tau$ and the values of Δb are slightly larger than for the previous energies. With regard to the diabatic correlation diagram of the He_2^+ system,[9] the mechanisms causing the two curve crossings can be considered as possible mechanisms for the He ($1s3p$, ^3P) excitation, corresponding to two electrons being elevated from the $(1s\sigma_g)(2p\sigma_u)^2\,{}^2\Sigma_g$ antibonding input channel to $(1s\sigma_g)^2(4d\sigma_g)\,{}^2\Sigma_g$ and $(1s\sigma_g)$-$(4d\pi_g)^2\,{}^2\Pi_g$.

In an attempt to clarify the parts played by short-range and long-range crossings, we are currently investigating the "companion" level ($3p$, ^1P).

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"Polarization-Free" Vacuum-Ultraviolet Excitation of Helium by Electrons

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"Polarization-free" excitation cross sections for the 1^1S-n^1P transitions of He have been measured from threshold to 2 keV using a crossed-beam technique. Results have been made absolute using the accurately known oscillator strengths. Maxima in the cross sections for the n^1P levels occurred around 100 eV and were found to be 106×10^{-19} cm^2 (2^1P), 31×10^{-19} cm^2 (3^1P), and 13×10^{-19} cm^2 (4^1P).

Previous measurements of optical excitation functions in the vacuum ultraviolet have suffered from two major disadvantages. In many instances signal intensities have been so low that investigators have had to work at pressures where absorption or imprisonment of resonance radiation is occurring. Secondly, the difficulty of dealing with polarization effects in this spectral region has meant that excitation functions have been presented whose shapes may have been radically altered by the polarizing effect of the detecting spectrograph. In the present experiment these difficulties have been avoided in the following way.

A crossed-beam arrangement has been used which has enabled local pressures in the neighborhood of the electron beam to be relatively high (about 10^{-4} Torr) while maintaining background pressures less than 5×10^{-7} Torr. Freedom from absorption effects was checked by monitoring the variation of output light intensity with gas-beam pressure in the usual way. Departure from linearity of this graph occurred at a pressure where calculations showed appreciable divergence of the beam would be expected.

In order to obtain "polarization-free" excitation functions the electron beam was aligned at angles of 54° 44′ to the optic axis and of 45° to the spectrograph slit in the manner suggested by Clout and Heddle.[1] In this way any effects due to polarization of the light from the interaction region or to the polarizing effect of the spectrograph are eliminated. This is the first time that "polarization-free" vacuum ultraviolet excitation functions have been presented.

A simple electrostatically focused four-element electron gun was used. This was capable of producing beams of a few hundred microamperes. An energy spread of approximately 500 mV was obtained using a 10-μA beam current. This was deduced from a study of threshold data. A Seya-Namioka $\frac{1}{2}$-m vacuum monochromator was used to isolate the lines being monitored and a Channeltron multiplier was used as the detector. The pulses from this were amplified and counted. The background count rate was one every few seconds. With the very weak emissions, counting rates were also of this order and so long data acquisition times were used to improve the statistics. The electron energy could be varied from threshold up to 2 keV.

The Bethe-Born theory[2] predicts that at high energies the cross section for excitation of the n^1P levels from the 1^1S ground state should be given by the expression

$$\sigma_n = (4\pi a_0^2 R^2 f_n / W E_n) \ln(4 C_n W/R),$$

where a_0 is the first Bohr radius, R the Rydberg energy, f_n the optical oscillator strength of the 1^1S-n^1P transition, W the energy of the impinging electrons, E_n the excitation energy of the n^1P state, and C_n a constant. The theory predicts therefore that, in the region where it is applicable, a straight-line graph should result when $\sigma_n W$ is plotted against $\ln W$. Further, the extrapolation of this line to zero cross section should cut the energy axis at the appearance potential of the level, thus allowing the constant C_n to be evaluated. The slope of the line is proportional to the optical oscillator strength.

Figure 1 illustrates the excitation functions of the 2^1P, 3^1P, and 4^1P levels of helium obtained by monitoring the 584, 537, and 522 Å lines, respectively. The curves have been corrected to allow for cascading effects. In all cases a linear relationship between σE and $\ln E$ was obtained above electron energies of approximately 500 eV. The cross sections were made absolute by normalization of the slopes of these straight lines to the accurate oscillator strengths.[3,4] This procedure was justified not only from the linear relationship that had been obtained but also from the fact that the extrapolations of these lines cut the energy axis very close to the appropriate thresholds in accordance with the Bethe theory.

Broad maxima in the functions occurred at approximately 85, 95, and 105 eV for the 2^1P, 3^1P, and 4^1P levels, respectively. The magnitudes of the cross sections at these points were 106×10^{-19} cm^2 (2^1P), 31×10^{-19} (3^1P), and 13×10^{-19} cm^2 (4^1P). An additional measurement was made at 100 eV of the sum of the line cross sections for lines of wavelength less than 522 Å, i.e., lines originating on levels with $n \geq 5$, assuming that the quantum yield of the detecting apparatus remained constant over the small wavelength interval below 522 Å where these lines occur. This yielded a value of 15×10^{-19} cm^2. Signals were too weak to allow isolation of the individual lines.

Other vacuum uv optical measurements of these levels have been carried out by Moustafa Moussa, De Heer, and Schutten[5] and by Van Eck and De Jongh.[6] The former group were unable

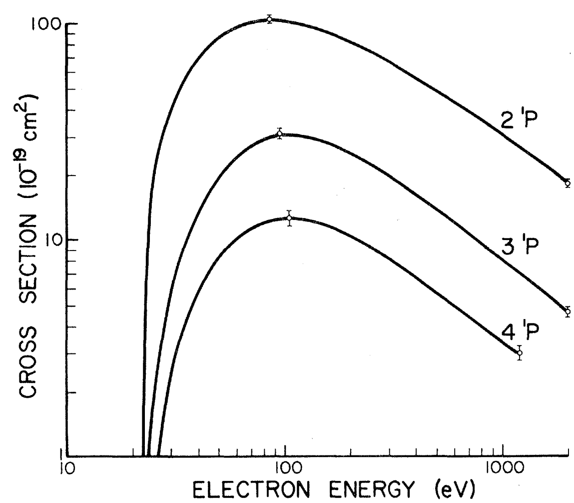

FIG. 1. Variation of the excitation cross sections of the 2^1P, 3^1P, and 4^1P states of He with electron energy. The error bars indicate the statistical fluctuations.

to correct for polarization effects and the latter made the assumption that the polarization of light from the beam was independent of principal quantum number n. By making separate measurements in which the electron beam was directed first along the slit of the spectrograph and then perpendicular to it, they were able to estimate the polarizing effect of the spectrograph. Neither Moustafa Moussa, De Heer, and Schutten[5] nor Van Eck and De Jongh[6] were able to make measurements at pressures where there was no imprisonment of resonance radiation.

Jobe and St. John[7] have investigated the cross section of the 2^1P level using measurements on the infrared 2^1S-2^1P transition. Various experimenters[8-10] have measured the cross section of this level over a limited energy region using electron-scattering techniques. Numerous optical measurements have been made of the cross sections for the $n \geqslant 3$ levels as transitions from these levels lie in the readily accessible visible spectral region. Reference to these may be obtained in the papers by Moustafa Moussa, De Heer, and Schutten[5] and by Moiseiwitch and Smith.[11] Accurate Born-approximation calculations on the excitation of the n^1P states of He have been carried out by Bell, Kennedy, and Kingston[12] and by Kim and Inokuti.[2] A detailed comparison between our work and the other experimental and theoretical results will be presented later. Meanwhile the following general comments may be made.

Good agreement with Van Eck and De Jongh is obtained on the shape of the excitation functions and on the position of the maxima.

Considering the 2^1P level, the absolute values obtained lie a few percent below those of Van Eck and De Jongh and a few percent above those of Moustafa Moussa, De Heer, and Schutten. Our value lies 5% below the Born approximation value at 1000 eV, 9% below it at 400 eV and 20% below it at 100 eV. In recent absolute differential electron-scattering measurements at 5° scattering angle, Chamberlain, Mielczarek, and Kuyatt[10] found the cross section to be 31.5% below the Born value at 100 eV and 9% below the Born value at 400 eV.

Considering the 3^1P level, we find that the agreement with both Van Eck and De Jongh and with the Born calculations is better than 2% at 1000 eV. At 100 eV the value was closer (95%) to that of St. John, Miller, and Lin[13] than to those of other workers.

A full report of these measurements containing all the relevant experimental details and a full discussion of possible sources of error is now in the course of preparation.

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