cutoff should be due to the fact that in a real gas, two absorbers are not permitted to approach one another more closely than a distance of the order of an atomic radius, so that interactions between absorbers at smaller distances than this should not be allowed to contribute. This can be accounted for at least approximately without introducing any explicit correlation (which would spoil our formalism) by simply doctoring the interaction in such a way that two absorbers are nor allowed to interact if they are closer together than an atomic radius. This means that r_0 should be of the ordte of an atomic radius and independent of $\mathfrak{N}$, and that a is proportional to $1/\mathfrak{N}$.

The solution of Eq. (B-39) leads to an absorption linewidth of order of magnitude

$$\delta\nu \sim a^{1/2}\Gamma\sigma.$$

If a is of the order of unity, as assumed in B, then this result is in qualitative agreement with previous theories,[3] but too small by a factor of the order of 10^3 when compared with the most recent experiments.[4] The observed linewidth is much too large to be accounted for by the Doppler effect. With our revised cutoff procedure, however, order-of-magnitude agreement can be obtained. For example, under the conditions of Tomiser's experiments with sodium vapor,[4] we have

$$\mathfrak{N} \sim 10^{15}\ \text{cm}^{-3}.$$

If we assume $r_0 \sim 5\times 10^{-8}$ cm, then we find

$$a^{1/2} \sim 500,$$

in rough agreement with the experimental results. The only difference is that the theoretical linewidth is now proportional to the square root of the density, while the observed dependence appears to be linear. Nevertheless, there is at least order-of-magnitude agreement with all the actual experimental points, and the discrepancy which does exist can apparently be largely removed if there is a slit width correction as large as 0.1 Å. This situation will be discussed more fully in a forthcoming paper, in which the effect of translational motion of the absorbers is also taken into account.

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Polarization of the $\lambda = 5876$ Å and $\lambda = 6679$ Å Lines in Helium Excited by Electrons*

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The polarization of the lines $\lambda = 5876$ Å and $\lambda = 6679$ Å resulting from the excitation of helium by electrons was measured as a function of the bombarding electron energy. The dependence of the polarization on the helium pressure is also reported for these lines. The observations reported here conflict with the theory of the polarization of collision-induced radiation at the threshold energy for excitation.

INTRODUCTION

RECENTLY, the authors of this paper reported on the polarization of light resulting from the excitation of helium by a beam of monoenergetic electrons.[1] The reader is referred to this work for a discussion of the details of the experimental arrangement, a review of the theory, and references to previous work reported on this subject by other authors. The polarization as a function of the electron energy for eight lines in helium was reported previously. It is the purpose of this present work to report on one additional line, $\lambda = 6679$ Å, as well as to present improved results on $\lambda = 5876$ Å.

The theory on the polarization of light resulting from the excitation of helium by electrons, as reviewed by Percival and Seaton,[2] predicts a unique maximum value for the polarization of light at threshold. The predicted threshold value does not depend upon a detailed calculation of the collision process, but only on some knowledge of the description of the states of helium and on the conservation of angular momentum. As noted previously,[1] experimental results indicate that, instead of approaching this unique threshold value, the polarization definitely tends toward zero. The results presented in this paper on the polarization of the $\lambda = 5876$ Å and $\lambda = 6679$ Å lines do not yield the predicted threshold value but, again, indicate a trend towards zero polarization at threshold.

EXPERIMENTAL ARRANGEMENT

Although the details of the experimental arrangement have been described in a previous paper, essentials

* Work performed under the auspices of the U. S. Atomic Energy Commission.

[1] R. H. McFarland and E. A. Soltysik, University of California Radiation Laboratory Report UCRL-6749, 1962 (unpublished); Phys. Rev. **126**, 2090 (1962).

[2] I. C. Percival and M. J. Seaton, Phil. Trans. Roy. Soc. London **113**, 251 (1958).

TABLE I. Polarization formulas. (σ_{m_l} is the cross section for exciting the helium atom to a state with magnetic quantum number m_l.)

λ(Å)	Transition	Polarization formula (%)	Polarization at threshold (%)
5876	$3\,^3D_{3,2,1}\rightarrow 2\,^3P_{2,1,0}$	$P=213\left(\dfrac{\sigma_0+\sigma_1-2\sigma_2}{671\sigma_0+1271\sigma_1+1058\sigma_2}\right)\times 100$	31.7
6679	$3\,^1D_2\rightarrow 2\,^1P_1$	$P=3\left(\dfrac{\sigma_0+\sigma_1-2\sigma_2}{5\sigma_0+9\sigma_1+6\sigma_2}\right)\times 100$	60

of the experiment are as follows: A beam of electrons (modulated at a frequency of 100 cps by means of a square-wave voltage generator) of a given energy entered a free-field region where the electrons interacted with the atoms of helium gas at a known pressure. The electrons, confined by a magnetic field of 15 G, were collected; and the electron current was measured with a microammeter. The modulated light signal, resulting from the excitation of the helium atoms by the electrons, was viewed at right angles to the electron beam. The light passed through a KN-36 polarizer, which analyzed the polarization of the light, then passed into a Bausch & Lomb 500-mm monochromator, and finally onto the cathode surface of a photomultiplier tube. The resulting modulated electrical signal was amplified with a narrow-band, lock-in 100-cycle amplifier and phase detected. The dc output signal voltage of the phase-detector was measured by an electrometer used as a voltmeter. A 10-mV recorder was used to display the voltage. The polarization was measured by recording the light intensities with the polarized parallel and perpendicular to the electron beam. The polarization is defined as

$$P\equiv\frac{I_{\parallel}(90°)-I_{\perp}(90°)}{I_{\parallel}(90°)+I_{\perp}(90°)}\times 100\%,$$

where $I_{\parallel}(90°)$ is the intensity of the radiation whose electric vector is parallel to the electron beam viewed at right angles to the beam, and $I_{\perp}(90°)$ is the intensity of the radiation with its electric vector perpendicular to the beam.

In previous work[1] an EMI 6255*S* photomultiplier tube was used which has a photosensitive surface with an *S* response. This is not sensitive to the red end of the spectrum. Replacement of this tube by an RCA 7265 phototube, which has an *S*-20 reponse, allowed an extension of previous results to include measurements of λ=6679 Å and measurements of λ=5876 Å at lower pressures than previously possible.

EXPERIMENTAL RESULTS AND DISCUSSION

The λ=5876 Å line arising from the transitions $3\,^3D_{3,2,1}\rightarrow 2\,^3P_{2,1,0}$ is the triplet state counterpart of the λ=6679 Å line, which results from the transition $3\,^1D_2\rightarrow 2\,^1P_1$. The polarization predicted for these two lines according to Percival and Seaton[2] is given in Table I. One obtains the threshold value for *P* by setting σ_1 and σ_2 equal to zero. Experimental results for the excitation I/i and polarization function *P* as a function of electron energy are shown in Figs. 1 and 2 for different helium pressures. Although the maxima of the polarization curves fall substantially below the predicted maxima at threshold, by far the most significant observation is that the polarization tends towards zero as threshold is approached. This is in direct conflict with what is anticipated theoretically. This observation was previously noted[1] for other helium lines.

Figures 3 and 4 show the dependence of the excitation function and polarization for the two lines as a function

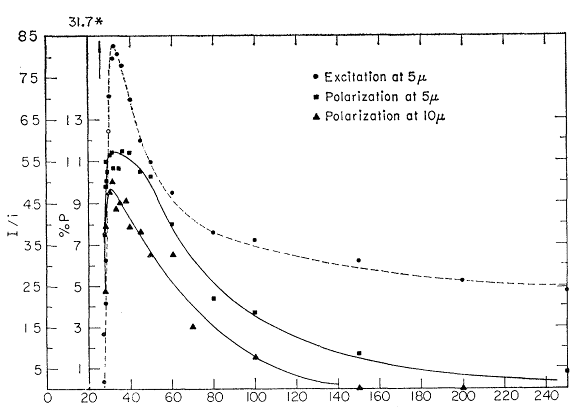

FIG. 1. Excitation and polarization vs electron energy, λ=5876 Å ($3\,^3D\rightarrow 2\,^3P$). Predicted threshold value of the polarization is 31.7%.

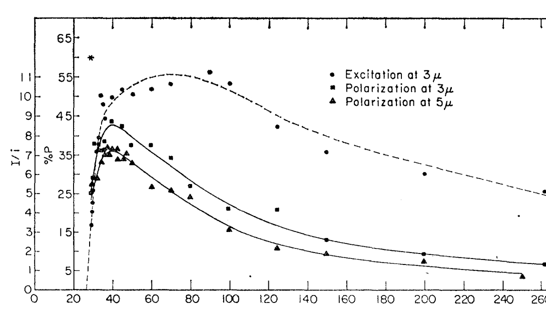

FIG. 2. Excitation and polarization vs electron energy, λ=6679 Å ($3\,^1D\rightarrow 2\,^1P$). Predicted threshold value of the polarization is 60%.

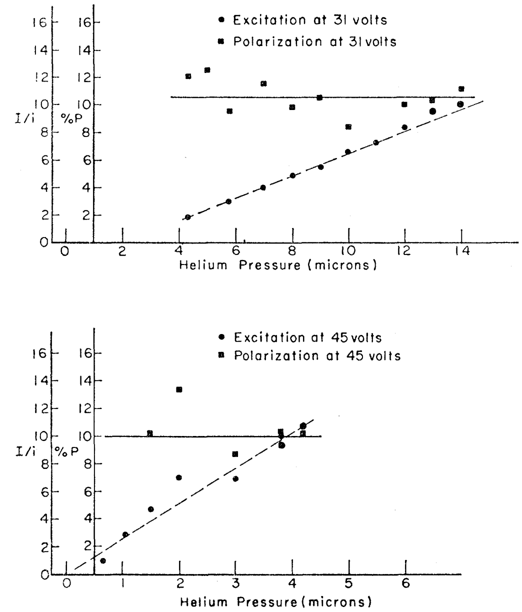

FIG. 3. Polarization and excitation vs helium pressure at 45 eV and 31 eV electron energy, $\lambda = 5876$ Å ($3\,^3D \rightarrow 2\,^3P$).

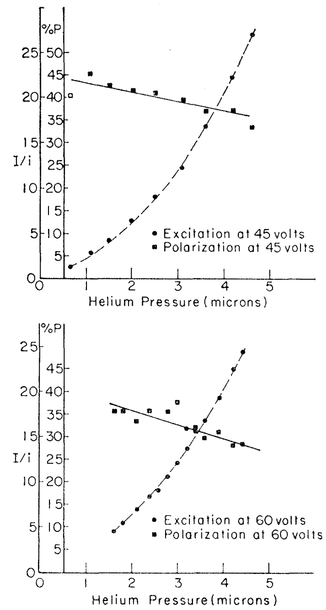

FIG. 4. Polarization and excitation vs helium pressure at 45 eV and 60 eV electron energy, $\lambda = 6679$ Å ($3\,^1D \rightarrow 2\,^1P$).

of helium pressure at two voltages. It will be noted that the excitation function for the $\lambda = 5876$ Å line, which corresponds to the transition $3\,^3D_{3,2,1} \rightarrow 2\,^3P_{2,1,0}$, exhibits a linear dependence on pressure which is expected if the radiation observed arises from electron impact only. On the other hand, the excitation function for the $\lambda = 6679$ Å line shows a small quadratic dependence on pressure which would indicate that at least some of the radiation observed is due to two-step atomic processes. This may be explicable in terms of resonance reabsorption of radiation.

The $3\,^1D$ state from which the $\lambda = 6679$ Å radiation arises may be populated by radiative transitions from ^1P states higher than the $3\,^1D$ state as well as by a direct collision with an electron. The ^1P state populations are enhanced by resonant reabsorption by ground-state atoms. Since this resonant reabsorption process is pressure dependent, it may account partially for the observed nonlinear pressure dependence of the excitation function and polarization of the $\lambda = 6679$ Å line.