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POLARIZATION OF THE RADIATION INDUCED BY ELECTRON IMPACT ON He AND Hg

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Synopsis

The polarization of a number of He and Hg spectral lines, excited by a beam of electrons, has been measured as a function of the electron energy. The transitions studied are: for helium $4^1D \rightarrow 2^1P$, $5^1D \rightarrow 2^1P$, $4^3S \rightarrow 2^3P$, $3^3D \rightarrow 2^3P$ $4^3D \rightarrow 2^3P$, for mercury $6^1D_2 \rightarrow 6^1P_1$, $6^3D_2 \rightarrow 6^1P_1$, $7^3S_1 \rightarrow 6^3P_1$, and $7^1D_1 \rightarrow 6^1P_1$.

The electron energy was varied from the threshold energy to a few eV above it. The results indicate that in most cases the polarization measured near the threshold is much lower than the theoretically predicted threshold polarization. For some transitions a detailed structure near threshold is observed in the polarization function. The observed behaviour of the polarization near threshold is discussed and a qualitative interpretation is presented.

1. *Introduction.* It can be shown[1,2]) that atomic line radiation, excited by an unidirectional beam of electrons, is in general partly polarized. In particular at the excitation threshold the polarization can be calculated exactly by using simple angular momentum considerations. However, except in a few cases, the experimental data give threshold polarizations which are much lower than the theoretically predicted[2]) values. The first polarization measurements on mercury[3,4]) and helium[5,6]) even suggested that the polarization tended to zero when the electron energy decreased to the threshold value, in contradiction with theory[1,2]), which predicts a maximum value for the polarization at the threshold (except in those cases, where zero polarization is predicted at all energies). More recent experiments[7–10]) have indicated that in many cases there is a sharp rise with decreasing energy or even a more detailed structure[10–12]) (within a few tenths of an eV from threshold) in the polarization, which in the earlier experiments could not be detected due to poorer energy resolution and less detection sensitivity. However, for most of the transitions studied the experimental polarizations, measured near threshold, are still much lower than the theoretical threshold values. This would indicate that in many cases the polarization rises so fast to a finite value at threshold that this

rise partly escapes experimental detection due to the energy spread in the electron beam used.

2. *The experimental arrangement.* Fig. 1 shows a schematic drawing of the complete setup. A sealed excitation tube (for a detailed description see refs. 13 and 14) contains the target gas, that can be excited by means of a beam of electrons of adjustable velocity. The light originating from a cross section (narrow disk) of the electron beam passes successively through a polarization filter and $\frac{1}{4}$-wave filter and is focused on the entrance slit of a grating monochromator. The light enters from a direction perpendicular to the electron beam. The light of a selected spectral line leaving the monochromator falls on the photo-cathode of a cooled multiplier tube, the temperature of which can be adjusted between -20 and -40 degrees centigrade with a stability of *ca.* 1 degree. Each photo-electron gives a current pulse at the anode of the photo-multiplier. These pulses are amplified with a fast

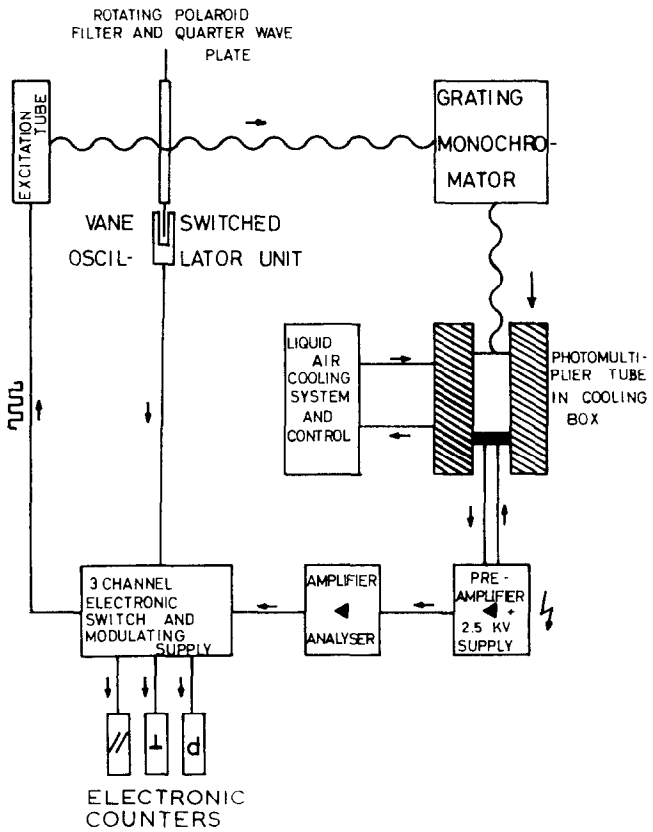

Fig. 1. Schematic diagram of the experimental setup used for the measurement of polarization functions of helium and mercury.

amplifier (rise time 1 μs), discriminated and finally recorded with electronic counters.

The degree of polarization is conveniently defined as follows:

$$P = (I_{//} - I_{\perp})/(I_{//} + I_{\perp}),$$

where $I_{//}$ and $I_{\perp}$ are the intensities of the emitted light with the electrical vector parallel and perpendicular to the electron beam, respectively. In order to measure the $I_{//}$ and $I_{\perp}$ components of the impact radiation use was made of a polaroid filter.

To eliminate the effects of possible drifts in the detection sensitivity or in the accelerating voltage, which may introduce large errors in the measured polarization (see ref. 10), it is necessary to keep the time intervals between $I_{//}$ and $I_{\perp}$ measurements very small. We have solved this problem by using a polaroid filter rotating in its own plane. The light detector system operates synchronously with the rotating polaroid filter in such a way that the light transmitted by the filter in the φ_t interval $(\pi/4, 3\pi/4)$ and the light transmitted in the interval $(3\pi/4, 5\pi/4)$ are detected separately, where φ_t is the angle between the principal axis of the polaroid and the direction of the electron beam at the time t. This is achieved by means of a specially designed electronic channel switch, which in fact divides the pulses, entering during

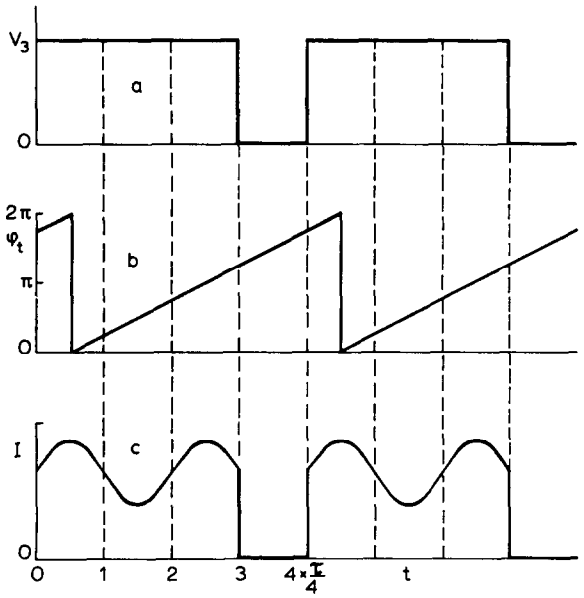

Fig. 2. The variation of V_3, φ_t and I as a function of time: V_3 = excitation chamber potential, φ_t = angle between the principal axis of the polaroid filter and the direction of the electron beam, and I = light intensity on the photo-cathode of the multiplier in case of a spectral line with an arbitrarily chosen positive polarization.

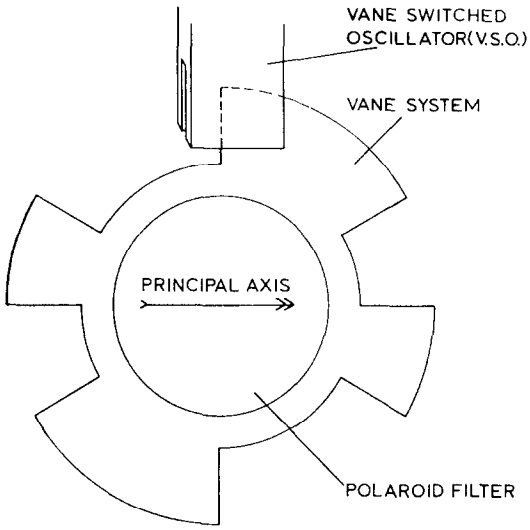

Fig. 3. Schematic drawing of the rotating polaroid system. If the metal vane system mounted on the polaroid filter rotates through the slot of the V.S.O., the latter gives a square-wave signal that is used to synchronize the electronic channel switch and the excitation chamber voltage to the rotating polaroid filter.

one revolution of the polaroid, over three different channels. The numbers of pulses in the above-mentioned quarter periods are counted in channel one and two, respectively; the third channel serves to measure simultaneously the dark current of the cooled photo-multiplier. Simultaneous measurement of the multiplier dark current is possible, since a square-wave voltage of the type as shown in fig. 2(a) is supplied to the excitation chamber. If the repetition frequency of this voltage is $1/\tau$, the accelerating voltage of the electrons has the adjustable value V_3 during $3\tau/4$ seconds and is zero during the next $\tau/4$ seconds. The polaroid filter rotates synchronously with the excitation chamber voltage, with a phase such that the angle φ_t varies as shown in fig. 2(b). For a spectral line with positive polarization the light intensity on the photo-cathode of the multiplier will then vary approximately as shown in fig. 2(c). By counting the multiplier pulses occurring in the time intervals $(0, \tau/4)$, $(\tau/4, 2\tau/4)$, $(2\tau/4, 3\tau/4)$, and $(3\tau/4, 4\tau/4)$ separately†, which can be done with the aid of the electronic channel switch, it is possible to determine the degree of polarization of the measured radiation.

The mutual synchronization of the rotating polaroid, the excitation chamber potential, and the electronic channel switch is accomplished in the following manner. The polaroid filter is provided with a metal vane system of the shape as shown in fig. 3. When the polaroid filter rotates the vanes

† The numbers of pulses in the first and third interval are equal (within the statistical spread) and are in fact counted in the same channel.

rotate through the slot of a so-called vane-switched oscillator (V.S.O.). The output of the V.S.O. is a square-wave voltage with a value of −6 volts when there is no vane in the slot and of zero volts otherwise. This signal is used as a steering signal to synchronize the excitation chamber voltage and the electronic channel switch directly to the rotating polaroid. The phase of this steering signal can be varied by changing the position of the vanes relative to the principal axis of the polaroid.

The above described system enables us to operate at an arbitrary frequency that can be varied by changing the transmission between the electromotor and the polaroid filter.

3. *Determination of the polarization.* The intensity of the light transmitted by the polaroid filter as a function of the angle φ_t between the principal axis and the electron beam is given by

$$I(\varphi_t) = C(I_{//} \cos^2\varphi_t + I_{\perp} \sin^2\varphi_t),$$

where C is a numerical constant. If the phase of the rotating polaroid is properly adjusted, then the numbers of pulses counted in the channels 1, 2 and 3 amount to

$$n_1 = 2K \int_{-\pi/4}^{\pi/4} I(\varphi_t)\, \mathrm{d}\varphi_t + 2D, \qquad n_2 = K \int_{\pi/4}^{3\pi/4} I(\varphi_t)\, \mathrm{d}\varphi_t + D, \quad \text{and} \quad n_3 = \mathrm{D},$$

respectively, where D is in the number of dark current pulses, depending on the counting time and being (within the statistical spread) the same in each channel, while K is a proportionality factor depending on the sensitivity of the apparatus and on the counting time. The factor 2 in the expression for n_1 arises from the fact that in channel 1 the pulses occurring in two intervals are counted (see footnote on page 308). After carrying out the integrals and making up the quantity

$$P^* = (\tfrac{1}{2}n_1 - n_2)/(\tfrac{1}{2}n_1 + n_2 - 2n_3),$$

we find

$$P^* = 2(I_{//} - I_{\perp})/\pi(I_{//} + I_{\perp}) = 2P/\pi,$$

where P is the degree of polarization of the emitted light. The procedure is now to determine experimentally P^*. This quantity has to be multiplied by $\pi/2 \approx 1.57$ in order to obtain the real polarization.

4. *Operating conditions.* The polarization curves of the helium lines have all been measured under the same experimental conditions. The pressure in the sealed excitation tube was 3×10^{-3} torr, which is sufficiently low to avoid most of the secondary processes such as multiple scattering, collisions of the second kind, *etc.* This pressure is, however, too high to avoid absorption

and re-emission of resonance radiation, which has a depolarizing effect on lines whose upper levels can combine with the ground state. This is the reason why we could not meaningfully measure the polarization curve of the 501.6 nm line ($3^1P \rightarrow 2^1S$), which is one of the strongest lines in the helium spectrum.

The electron current through the excitation chamber was about 20 μA. This current depended slightly on the excitation chamber voltage V_3. A variation of V_3 from 20 to 30 volts above the cathode caused a variation of less than 10% in the electron current. The voltage of the other electrodes ($V_1 = 20$ V, $V_2 = 5$V, $V_4 = 30$ V and $V_5 = 35$ V) were chosen so as to obtain a homogeneous and parallel electron beam.

The mercury lines were measured at a mercury pressure of approximately 10^{-3} torr (the saturated vapour pressure at room temperature) and at an electron beam current of about 15 μA. The Hg-tube showed a stronger dependence of the beam current on V_3 than the He-tube. For the Hg-tube a current variation of about 20% was observed when V_3 was varied from 8 to 15 volts. However, when measuring polarization this current variation presents no problem, since the polarization is determined by the ratio $I_{//}/I_{\perp}$, which is independent of the beam current. For the same reason variations (within certain limits) of the mercury vapour pressure are not important in our polarization measurements.

Judging from the observed widths of peaks in some excitation curves, the half-width of the energy spread in our electron beam amounts to about 0.35 eV. This amount is in fair agreement with what one may estimate on the basis of the cathode temperature, space charge, *etc.* (see ref. 14).

5. *Corrections.* The energy scales of the measured polarization curves must be corrected, since the real accelerating voltage of the electrons is not exactly equal to the voltage V_3 of the excitation chamber with respect to the cathode. The difference is caused by contact potentials, field penetration, and space charge. The correction is performed by shifting the onset of the excitation (polarization) curve to the spectroscopically known value of the excitation energy.

We have observed that the apparatus behind the polaroid filter (optics, monochromator and multiplier) did not have the same sensitivity for the two polarization components, $I_{//}$ and $I_{\perp}$. Moreover, this polarizing effect of the apparatus turned out to be wavelength dependent and slightly changing in time (the latter probably as a result of temperature variations of the cooled photo-multiplier). In the present apparatus we have eliminated, for the greater part, the effect of apparatus polarization by changing the light transmitted by the polaroid filter into circularly polarized light. This is achieved by means of the $\frac{1}{4}$-wave plate, which rotates together with the polaroid filter during the measurement. The principal axis of the $\frac{1}{4}$-wave plate makes an

angle of 45° with that of the polaroid. In this situation the light transmitted by the $\frac{1}{4}$-wave plate is circularly polarized and consequently the effect of apparatus polarization is eliminated. This elimination is of course only complete at the one wavelength the $\frac{1}{4}$-wave plate has been made for and which is 500 nm. At the other wavelengths the transmitted light is more or less elliptically polarized, and consequently the influence of apparatus polarization (if present) will still be effective (of course to a much smaller degree than without the $\frac{1}{4}$-wave plate). This effective apparatus polarization has been measured and appeared to vary from about 3% at 430.0 nm to 0% at 580.0 nm. The measured polarization curves have been corrected accordingly.

6. *Results and discussion.* The measured polarization curves (for energies from threshold to a few eV above) of 5 helium and 4 mercury lines are shown in the figs. 4 through 12. Each point in every curve is the average of at least 4 measurements, while in each measurement the counting time was taken so long that at least 10^4 pulses were registered in the $I_{//}$ or in the $I_{\perp}$ channel. Near the threshold where the light intensities are small and the dark current is a large fraction of the signal, the statistical uncertainties can become quite appreciable as is indicated by the error bars in the figures. For energies larger than 0.5 eV above threshold the statistical errors vary from 1 to 3% polarization for the different curves; except for the 435.8 nm line of Hg, where the statistical error is not more than 0.3% polarization.

It appears that for most of the lines measured the polarization varies

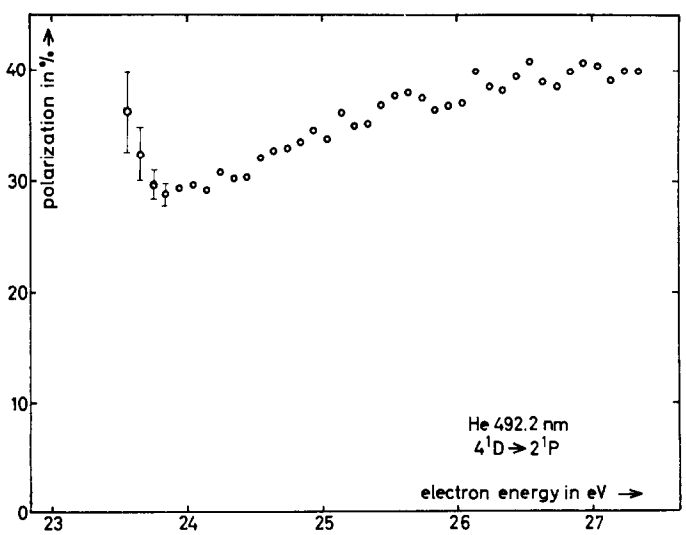

Fig. 4. Measured polarization function of the 492.2 nm line of helium.
Ordinate = $100\,(I_{//} - I_{\perp})/(I_{//} + I_{\perp})$.

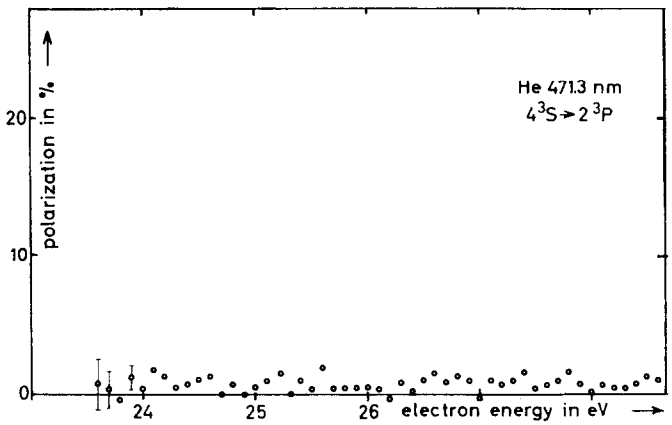

Fig. 5. Measured polarization function of the 471.3 nm line of helium.

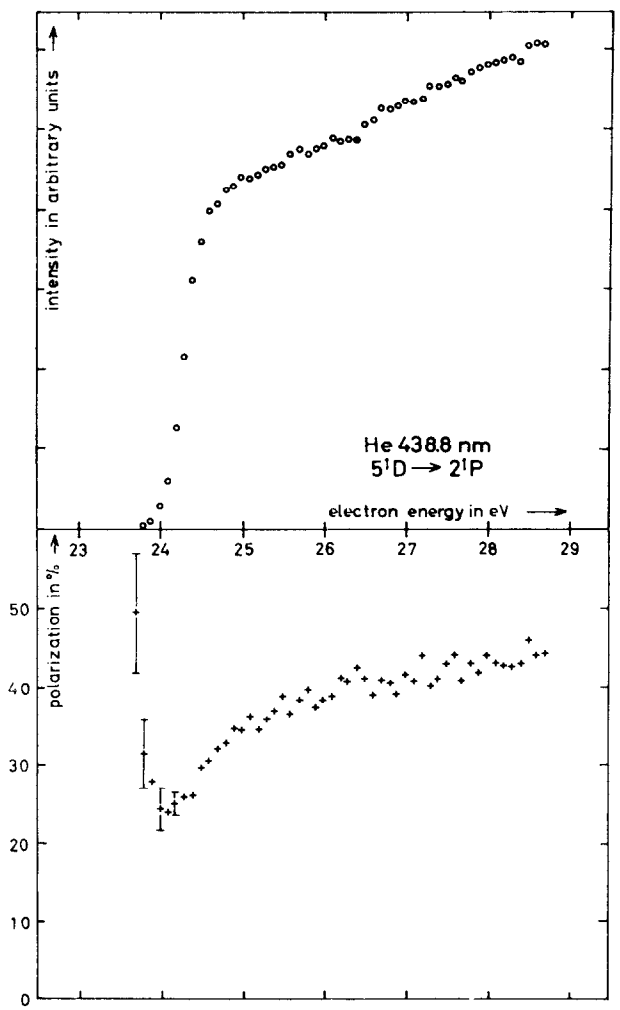

Fig. 6. Measured excitation and polarization function of the 438.8 nm line of helium.

rapidly near threshold. For 5 lines, i.c. He 492.2 nm, He 587.6 nm, He 447.2 nm, Hg 579.1 nm and Hg 577.0 nm, the measured polarization in the immediate vicinity of the thresholds is appreciably smaller than the corresponding theoretical threshold values[2]), which amount to 60%, 31.7%, 31.7%, 60% and 60%, respectively (see also table I). Apparently for these lines the polarization decreases so fast that we cannot measure it correctly due to the limited energy resolution of our electron beam. In some polarization curves (He 587.6 nm, Hg 579.0 nm and Hg 577.0 nm, for instance) there is a clear detailed structure in the threshold region, which obviously is related to detailed structure in the corresponding excitation curves.

According to theory[2]) where spin-orbit coupling is neglected the lines He 471.3 nm and Hg 435.8 nm should be unpolarized. Our results for the He 471.3 nm line are in accord with this theory (the small apparent polarization is probably caused by the glass of the excitation tube, which is not accounted for in the apparatus polarization). For the Hg 435.8 nm line, however, we find a polarization of about −2% near 9 eV. This is not surprising since spin-orbit coupling is certainly appreciable for a heavy atom such as mercury.

Our results on helium may be compared with recent measurements by

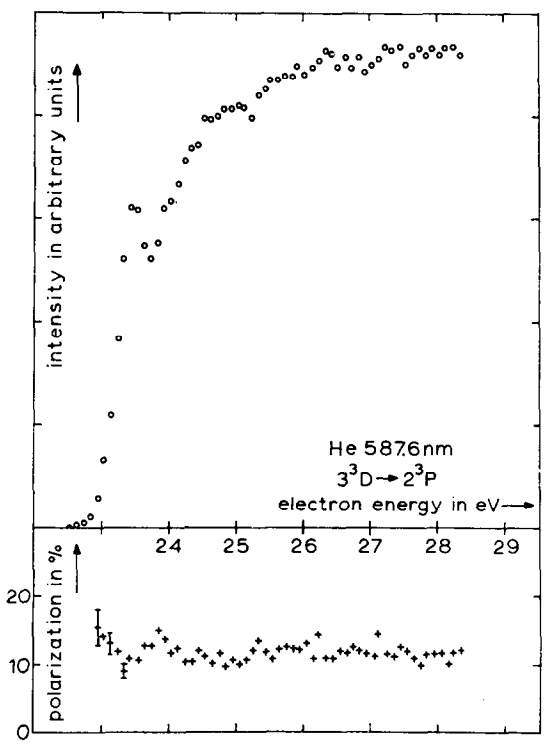

Fig. 7. Measured excitation and polarization function of the 587.6 nm line of helium.

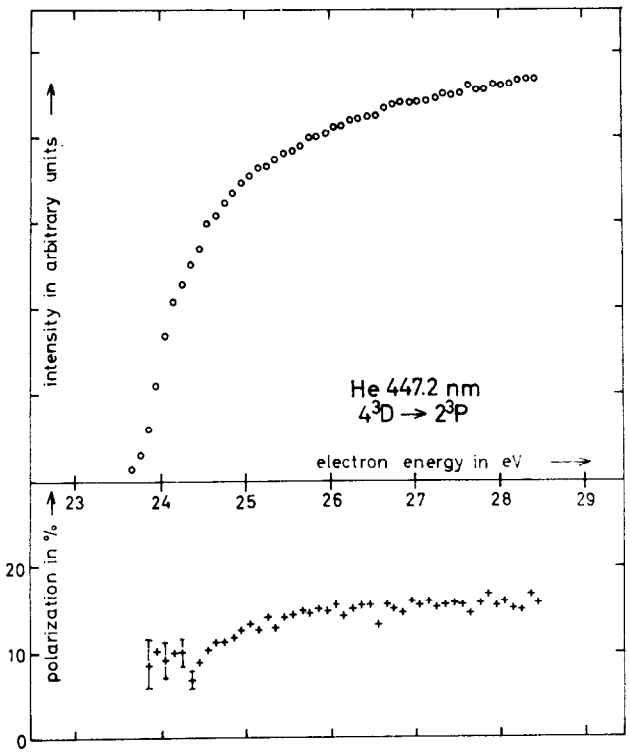

Fig. 8. Measured excitation and polarization function of the 447.2 nm line of helium.

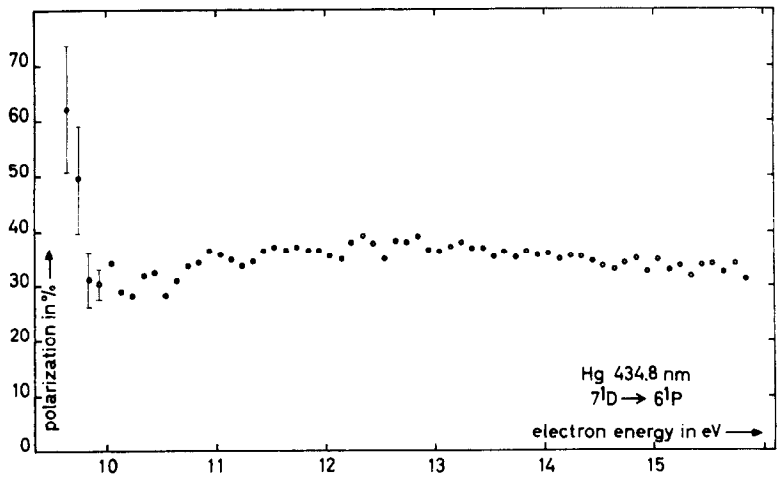

Fig. 9. Measured polarization function of the 434.8 nm line of mercury.

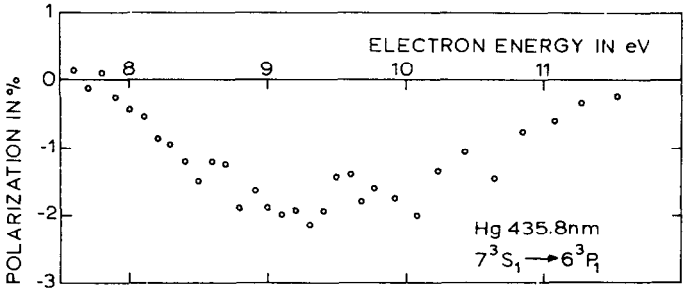

Fig. 10. Measured polarization function of the 435.8 nm line of mercury.

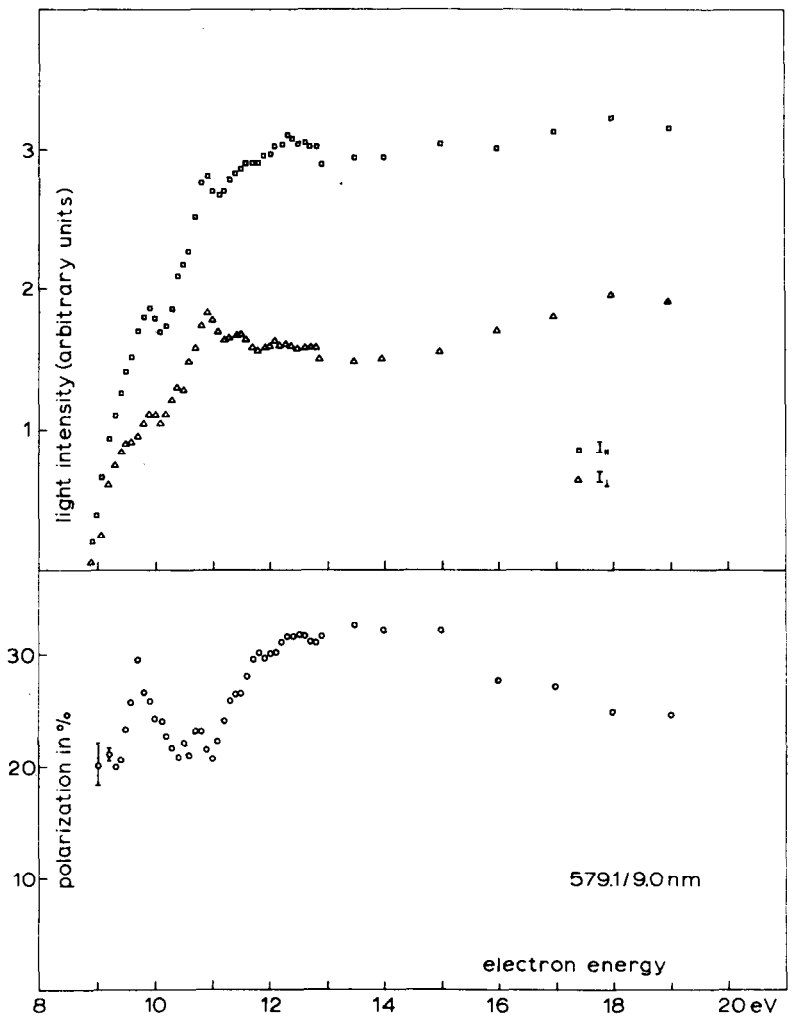

Fig. 11. Measured excitation and polarization function of the 579.1/9.0 nm line of mercury. The $I_{//}$ and $I_\perp$ components of the excitation function have been plotted separately.

Mc Farland[8]). Our curve for the 438.8 nm line appears to be very similar to the one measured by McFarland. For the 492.2 nm line McFarland finds a steeper rise near threshold than we do. This would indicate that the energy resolution in McFarlands experiment is better than in our experiment. The resolution of our electron beam amounts to about 0.3 eV. In order to explain the threshold behaviour of some of the excitation and polarization curves measured by McFarland (see for instance fig. 7 of ref. 8) a resolution of about 0.05 eV must be assumed. It is not clear how McFarland could reach such a resolution without employing a more sophisticated device like an electron monochromator or R.P.D. method.

Recent polarization measurements on the 492.2 nm line of helium by Soltysik *et al.*[15]) are in reasonable agreement with our results for that line. At 28 eV they observe a polarization of about 40%, the same value as we do. We observe a gradual decrease of the polarization towards threshold with a rise within 0.3 eV from threshold. This behaviour cannot be observed in the curve of Soltysik *et al.*, probably due to poorer statistics and energy resolution (0.7 eV).

Heddle and Keesing[9]) recently measured the polarization curves of the 492.2, 501.6, 388.9, and 471.3 nm lines of helium. Their results for the 492.2 nm line agree qualitatively with ours in that the polarization rises close to threshold. They find, however, larger values for the polarization near threshold than we do. For the 471.3 nm line they find zero polarization at al energies in accord with our results.

Apart from our measurements the only recent measurement on the polarization of mercury lines are those of Fedorov and Mezentsev[16,17]).

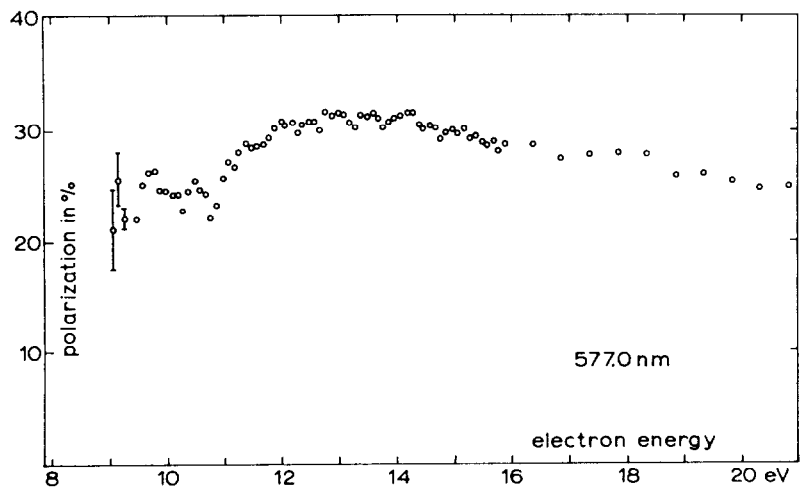

Fig. 12. Measured polarization function of the 577.0 nm line of mercury.

These authors confirmed our[11]) earlier observation that polarization curves sometimes show detailed structure in the threshold region. Their results are qualitatively in reasonable agreement with ours. In particular their polarization curve of the 577.0 nm line is very similar to our curve. Fedorov and Mezentsev find maxima and minima at nearly the same energies as we do, although the magnitude of the various maxima do not quite agree. In the curve for the 434.8 nm line Fedorov and Mezentsev find a rather pronounced dip near threshold which does not show up in our measurement. It is impossible that we could have missed this dip due to insufficient energy resolution, since the dip observed by Fedorov and Mezentsev is more than 1.5 eV broad. The reason for this discrepancy is not clear.

7. *Interpretation of the experimental results.* As has been mentioned in the introduction, at threshold the polarization can be calculated exactly. In table I the theoretical threshold polarizations[2]) of the He and Hg lines we studied are compared with the experimental values we measured *near* threshold. The experimental numbers in the table cannot be identified with threshold polarizations since a polarization measurement at the very threshold where the light intensity vanishes, is of course impossible. As the energy spread in the electron beam is about 0.3 eV, each experimental number in the table represents in fact a weighted average of the polarization in the energy range from threshold to about 0.3 eV above it. It is clear from the table that for some lines the experimental "near threshold" polarizations are much smaller than the theoretically predicted threshold values, which we consider to be correct. This can only be understood if for these lines the polarization decreases very fast immediately above threshold; the decrease being so fast that it escapes (at least partly) experimental detection due to the finite

TABLE I

Comparison between theoretical threshold polarizations and experimental values measured near threshold (see text).

	wave length (in nm)	transition	theoretical thresh. polariz.	experim. "near thresh." polariz.
Helium	492.2	$4^1D \rightarrow 2^1P$	60%	ca. 33%
	438.8	$5^1D \rightarrow 2^1P$	60%	,, 50%
	471.3	$4^3S \rightarrow 2^3P$	0%	,, 0%
	587.6	$3^3D \rightarrow 2^3P$	31.7%	,, 16%
	447.2	$4^3D \rightarrow 2^3P$	31.7%	,, 10%
Mercury	579.1	$6^1D_2 \rightarrow 6^1P_1$	60%	,, 20%
	577.0	$6^3D_2 \rightarrow 6^1P_1$	60%	,, 22%
	435.8	$7^3S_1 \rightarrow 6^3P_1$	0%	,, 0%
	434.7	$7^1D_2 \rightarrow 6^1P_1$	60%	,, 62%

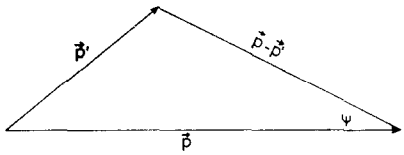

Fig. 13. Definition of the angle ψ. The momenta of the incident and scattered electrons are $\boldsymbol{p}$ and $\boldsymbol{p}'$, respectively, and $\boldsymbol{p} - \boldsymbol{p}'$ is the momentum transfer.

energy resolution of the electron beam. In the following we shall investigate whether such a behaviour can be expected.

Bethe[1]) derived the following general formula for the polarization of the impact radiation:

$$P = P_0(3\overline{\cos^2\psi} - 1)/\{2 - P_0(1 - \overline{\cos^2\psi})\}.$$

In this formula P_0 is the theoretical threshold polarization and ψ is the angle between the momentum of the incident electron and the direction of the momentum transfer (see fig. 13); note that $0 \leq \psi \leq \pi/2$. At a particular incident energy there is of course a distribution of ψ's determined by the differential cross section for excitation of the level under consideration. Therefore, as indicated in the formula, averaging over all possible angles ψ has to be carried out. In the derivation of the above formula it has been assumed that the orbital angular momentum transferred to the atom is always perpendicular to the momentum transfer $\boldsymbol{p} - \boldsymbol{p}'$ (see fig. 13). This assumption is correct at threshold and at very high energies where the first Born approximation is valid; it is also correct as long as the scattering can be treated as a binary encounter collision between the incident and atomic electron (leaving the spins out of consideration). On the basis of the Bethe formula, we can estimate the minimum incident electron energy necessary to get a polarization of, say 0.6 times the threshold value, for instance in the case that $P_0 = 0.6$. The function P decreases monotonically with decrease of $\overline{\cos^2\psi}$ and we find $P < 0.6\ P_0$ ($= 0.36$) if $\overline{\cos^2\psi} < 0.70$ or if $\overline{\sin^2\psi} > 0.30$. From fig. 13 it follows that $\sin^2\psi$ is always smaller than or equal to $p'^2/p^2 = E'/E$ (E and E' are the kinetic energies of the incident and scattered electron, respectivily). Hence, to get a polarization smaller than 0.6 times the threshold polarization (of 60%) E'/E should at least amount to 0.30. For the 492.2 nm line of helium, for instance, this means that the incident electron energy would have to be at least 34 eV (about 10 eV above threshold). This is evidently in disagreement with the experimental results. The polarization of the 492.2 nm line is smaller than 36% at an energy only 0.3 eV above threshold. Apparently the basic assumption in the Bethe formula (namely that the orbital angular momentum transferred to the atom is perpendicular to the momentum transfer), although correct right at threshold, ceases to be valid at less than 0.5 eV above threshold.

In the case of singlet excitation, without spin-orbit coupling, the angular momentum transferred to the atom amounts to $\Delta \boldsymbol{J} = \boldsymbol{j} - \boldsymbol{j}'$, where $\boldsymbol{j}$ and $\boldsymbol{j}'$ are the orbital angular momenta of the incident and scattered electron, respectively. For incident energies a little above threshold p' is much smaller than p and thus the direction of $\boldsymbol{p} - \boldsymbol{p}'$ remains practically parallel to $\boldsymbol{p}$. Hence, as long as $\boldsymbol{j}' = 0$ (s-wave scattering), $\Delta \boldsymbol{J}$ remains practically perpendicular to $\boldsymbol{p} - \boldsymbol{p}'$, and one would expect the Bethe-formula to hold near threshold. Since this is evidently not the case a few tenths of an eV above threshold one must conclude that it must be possible for the scattered electron to carry away an angular momentum of one or more $\hbar$, despite of its small excess energy of, say, 0.3 eV. This conclusion is in agreement with recent results obtained in electron scattering experiments[19,20]). It has been found[10,18,19,20]) that the excitation of many atomic levels near threshold for a large part proceeds via intermediate negative ion compounds, giving rise to sharp structures in the corresponding excitation curves. In studying the resonances in the $n = 2$ excitation of He as a function of angle, Ehrhardt *et al.* found that the excitation of the 2^3S state[19]) (and to a smaller degree the 2^1S state[20])) near threshold predominantly proceeds via two strong resonances at 20.45 and 21.00 eV, respectively. The former is a ^2P compound state while the latter has a ^2D configuration. Thus, when auto-ionizing into one of the 2S-states of He, these resonances give rise to strong p- and d-wave components in the scattering amplitude. The direct (nonresonant) scattering directly above threshold consists probably for the greater part of s-wave because of the small excess energy of the scattered electrons. The real scattering cross section results from interference between the two (resonance and nonresonance) amplitudes.

In our polarization measurements we are not dealing with the $n = 2$ but with the $n = 3$, 4 and 5 levels of He. However, in optical excitation function measurements[21,22]) resonances have also been found in the excitation of the $n = 3$, 4 and 5 levels, in many cases lying within 0.5 eV from treshold. It is clear that these higher lying resonances can also give rise to p- and d-wave scattering near the thresholds of the $n = 3$, 4 and 5 states of He with which we are dealing.

Summarizing we may say: if just above threshold a negative ion resonance occurs, the scattered electron may carry away an angular momentum of one or more $\hbar$ (depending on the configuration of the intermediate compound state), which in principle may have different directions with respect to $\boldsymbol{p}$ (direction of the incident beam). The result is a disorientation of $\Delta \boldsymbol{J} = \boldsymbol{j} - \boldsymbol{j}'$ and consequently a polarization that may be considerably smaller than at threshold, where $\Delta \boldsymbol{J} = \boldsymbol{j}$ is perpendicular to $\boldsymbol{p}$.

In some polarization curves a clear structure can be observed at energies where also structure occurs in the excitation curves. This is indeed to be expected if indirect excitation via negative-ion resonances is to be considered

responsible for the rapid decreases in the polarization curves near threshold.

An interesting check on the validity of the above pictured (qualitative) interpretation is provided by the recent polarization measurements of Whitteker and Dalby[23]). These authors measured the polarization curves of the $2^3P \rightarrow 2^3S$ and the $3^3P \rightarrow 2^3S$ transitions in helium. The lowest resonance (in energy) in the 2^3P excitation occurs at about 22.5 eV (see ref. 18), which is about 1.5 eV above the threshold, while in the 3^3P excitation a resonance occurs at less than 0.4 eV from threshold (see ref. 21). If our interpretation is right one would expect the measured "near threshold" polarization of the $2^3P \rightarrow 2^3S$ line to be much closer to the theoretical threshold polarization than that of the $3^3P \rightarrow 2^3S$ line. And this is precisely what Whitteker and Dalby find. When extrapolating their measurements to threshold they find a threshold polarization of $(32 \pm 6)\%$ for the $2^3P \rightarrow 2^3S$ line and $(15 \pm 3)\%$ for the $3^3P \rightarrow 2^3S$ line. The theoretical threshold polarization amounts to 36.6% for both lines.

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