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LIFETIME OF THE 2^1P STATE OF He †

W. L. Williams and E. S. Fry
The University of Michigan, Ann Arbor, Michigan
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The lifetime of the 2^1P state of helium has been measured, using a modified Hanle-effect method, as $\tau = (5.8 \pm 0.4) \times 10^{-10}$ sec. The oscillator strength for the 2^1P-1^1S transition determined from the lifetime is $f = 0.27 \pm 0.02$.

Comparison of the theoretical and experimental f values for the low-lying P states in helium provides an important check on the approximation used for the two-electron wave functions. Recently Kuhn and Vaughan[1] reported an experimental f value for the 1^1S-2^1P resonance transition in helium which is larger than the computed value[2] by some 30-40%. A discrepancy of this size is rather surprising considering the accuracy of the wave functions which were used to obtain the calculated value. It has been proposed[3] that the experimental f value, which was determined from interferometric profile analysis of emission lines to the 2^1P state, reflects the effects of resonance broadening. We have determined the f value from a measurement of the 2^1P lifetime. Our result is in good agreement with the computed value.

We have measured the 2^1P lifetime utilizing a novel modification of the zero-field level-crossing (Hanle-effect) method.[4] In the usual Hanle experiment the incident and scattered radiation have the same wavelength. This method has serious disadvantages in measurements on atomic states for which the strong radiative transitions are in the vacuum ultraviolet since it is difficult to construct light sources and windows. This is particularly true for the present experiment where the wavelength of the strong transition (2^1P-1^1S) is 584 Å. We have eliminated these problems by using the method illustrated in Fig. 1. A beam of metastable 2^1S ($\tau = 0.14$ sec) He^4 atoms is produced by electron bombardment and appropriately collimated to pass along the axis of a Helmholtz pair. This beam also contains ground-state and metastable 2^3S atoms. A beam of resonant 2^1S-2^1P, 2-μ He^4 radiation with plane of polarization perpendicular to the magnetic field (H) axis is incident on the helium beam. Resonant 2^1P-1^1S, 584-Å radiation is observed at right angles to the magnetic field and incident light directions (90°-90°-90° geometry) with a Channeltron multiplier.[5] This type of multiplier is also used to monitor the total metastable beam

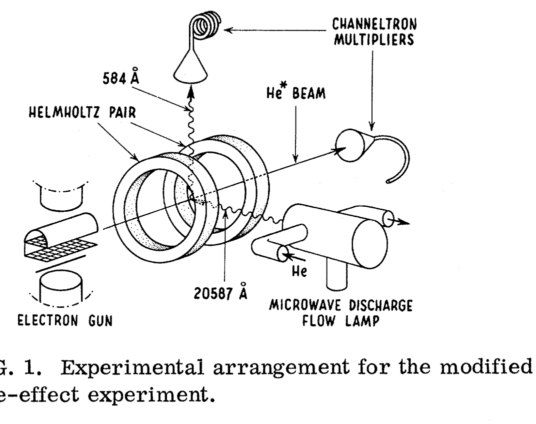

FIG. 1. Experimental arrangement for the modified Hanle-effect experiment.

as indicated. We have established that the radiation observed is resonant 584 Å by the following unambiguous checks. We observe scattered radiation using a He^4 discharge lamp with and without a 2-μ filter. We do not observe scattered radiation when the 2-μ line is filtered out. Further, we do not observe scattered radiation using the 2-μ line from a He^3 discharge lamp.[6]

The predicted scattering rate for the 584-Å radiation in our experiment is

$$R \propto 1-[1+(\omega\tau)^2]^{-1} \tag{1}$$

with

$$\omega = 2g\mu_0 H/\hbar. \tag{2}$$

Here τ and g are the 2^1P lifetime and g value, respectively. The lifetime of the 2^1P state of He is related to the half-width, $H_{1/2}$, of the inverted Lorentzian line, by

$$\tau = 5.7\times10^{-8} H_{1/2}^{-1} \text{ sec}, \tag{3}$$

where g has been taken as 1 and $H_{1/2}$ is in gauss. One example of the dependence of the 584-Å normalized counting rate on magnetic field is shown in Fig. 2. A fitted Lorentzian is also shown. The line shape shows a deviation from the Lorentzian in the wings similar to the results from xenon obtained by Anderson.[7] We have no explanation for this at the present time. We include the possible effects of this deviation in the error quoted for the lifetime. The pressure indicated is helium background pressure. We observed no pressure dependence of the half-width over a range of a factor of 2. The result of our measurements is

$$H_{1/2} = 98 \pm 8 \text{ G}. \tag{4}$$

This experimental value and the half-width predicted from the computed f value are indicated by the arrows in Fig. 2. The lifetime of the 2^1P state is

$$\tau = (5.8 \pm 0.4)\times10^{-10} \text{ sec}. \tag{5}$$

The contribution to this lifetime from the 2^1P-2^1S transition is negligible within our experimental accuracy. We thus derive the 2^1P-1^1S oscillator strength, using (5),

$$f = 0.27 \pm 0.02. \tag{6}$$

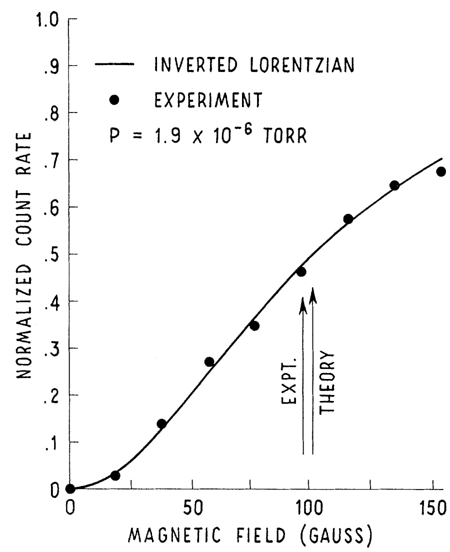

FIG. 2. Dependence of the 584-Å scattering rate on the magnetic field.

This is to be compared with the previous experimental value[1] of $0.37_7 \pm 0.03_5$ and the computed value[2] of 0.276. The present measurements thus confirm the calculated value to ~8 %. These measurements will be refined and reported in detail later.

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[2]B. Schiff and C. L. Pekeris, Phys. Rev. 134, A638 (1964).

[3]H. G. Kuhn, E. L. Lewis, and J. M. Vaughan, Phys. Rev. Letters 15, 687 (1965).

[4]For a discussion of the Hanle effect, see A. C. G. Mitchell and M. W. Zemansky, Resonance Radiation and Excited Atoms (Cambridge University Press, New York, 1961).

[5]We are indebted to C. W. Hendee of Bendix Corporation for supplying the Channeltron multipliers used in this work.

[6]The wavelength of the 2-μ line in He^4 differs from that in He^3 by approximately 1 Å. See M. Fred et al., Phys. Rev. 82, 406 (1951).

[7]D. K. Anderson, Phys. Rev. 137, A23 (1965).