POLARIZATION OF RESONANCE RADIATION IN MERCURY[1]

BY HARRY F. OLSON

ABSTRACT

$1^1S_0-2^3P_1$ of mercury excited by plane polarized light shows incomplete polarization both in the absence and in the presence of a weak field parallel to the electric vector. The amount of initial polarization depends upon the relative intensities of the hyperfine structure lines in the exciting light. The polarization with various relative orientationsof field and light vector and the variation of polarization with field intensity in weak fields may be interpreted successfully by means of a semi-classical model, with proper relative intensities parallel and prependicular to the light vector, rotating after excitation with an angular velocity $geH/2mc$ and emitting a damped wave. From curves connecting depolarization, rotation of maximum of polarization, etc., with field intensity α, the damping constant, has been found to be 1.02 ($\pm$0.02) 10^7 sec^{-1}.

IT has been found, in agreement with recent results of von Keussler,[2] that the behavior of the polarization of mercury resonance radiation in weak magnetic fields may be completely accounted for by a simple resonator rotating with the angular velocity of the Larmor precession and emitting a damped wave. The simple isotropic oscillator however is not an adequate model; it is necessary to assume that excitation of the oscillator by plane polarized light gives rise to a certain amount of radiation in the plane perpendicular to the electric vector of the exciting light. Since the $1^1S_0-2^3P_1$ line shows a 3/2 normal Zeeman pattern it might be expected that the isotropic oscillator would suffice as a model. That it does not is due to the peculiar behavior of the outer two hyperfine structure lines as shown by Ellett[3] and McNair. The three remaining hyperfine structure lines behave in accordance with the predictions of the theory of the anomalous Zeeman effect for a $1^1S_0-2^3P_1$ line.

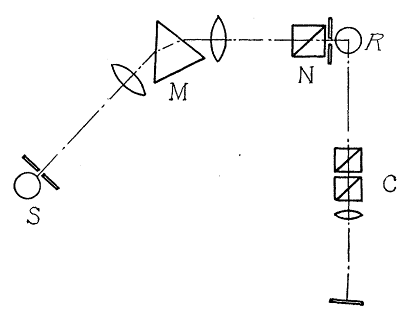

Fig. 1. Arrangement of apparatus.

The behavior of the isotropic oscillator as a model for the phenomena in question has been discussed by Eldridge[4] and Breit.[5] The introduction of the non-isotropic oscillator involves no more than a slight alteration of the constants

[1] Read at the Chicago Meeting of the American Physical Society, November 26, 1926. Publication has been withheld to check the discrepancy with von Keussler's results for the mean life of the excited atom.

[2] von Keussler, Phys. Zeits. **27**, p. 313 (1926).

[3] Ellett and McNair, Phys. Rev. **31**, p. 180 (1928).

[4] Eldridge, Phys. Rev. **24**, p. 234 (1924).

[5] Breit, Jour. of Opt. Soc. **10**, p. 439 (1925).

of their equations for the case discussed by them, and their analysis of course leads at once to the equations for other relative orientations of light vector, magnetic field and direction of observation.

The arrangement of apparatus is shown in Fig. 1 where S is a water-cooled quartz mercury arc, M a monochromator, N a nicol prism for polarizing the exciting light in any azimuth, C two Wollaston prisms and a camera with a quartz lens. The familiar Cornu method of determining polarization was used. This involves no assumption as to the density-exposure relations save that two adjacent areas exposed simultaneously to the same intensity for the same length of time will show equal blackening. Densities were measured on a microphotometer and from a series of exposures at intervals of 30′ for the relative setting of the two Wollaston prisms the positions of exact equality could be obtained quite accurately.

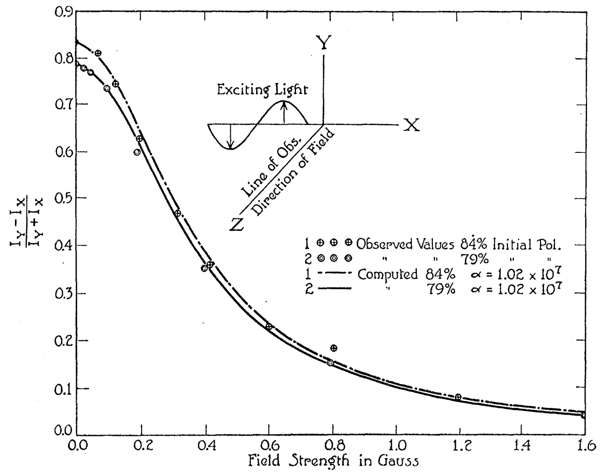

Fig. 2.

The results and their comparison with the curves calculated for the model discussed above are best presented graphically. Fig. 2 is for the case discussed by Eldridge[4] and by Breit[5] and examined experimentally by Wood[6] and Ellett and by von Keussler.[2] Curve 2 was taken with the arc operating on 3.5 amperes which gave an initial polarization of 79 percent. Curve 1 was taken with another arc operating on 1 ampere. This source gave an initial polarization of 84 percent. Operating this latter arc on 0.4 amperes approximately 86 percent initial polarization was obtained. The intensity under these circumstances is very feeble and not suitable for making the large number of observations required for a curve.

The different initial polarizations apparently are due to a change in the relative intensity of the hyperfine structure lines of the exciting light. As Ellett[3] and McNair have shown the incomplete polarization of λ2537 in the absence of an external field is due to the behavior of the outer two hyper-

[6] Wood and Ellett, Phys. Rev. **24**, p. 342 (1924).

fine structure lines. A change in the intensity of these lines relative to the other three will obviously alter the initial polarization.

The same value of the damping constant α is obtained for both types of excitation. This shows either that the three central components suffer the same change in intensity with the two types of excitation or that the mean lives[7] of the three components are the same.

The curve in Fig. 3 is for the relative orientations of light vector, magnetic field and direction of observation represented in the same figure. The rela-

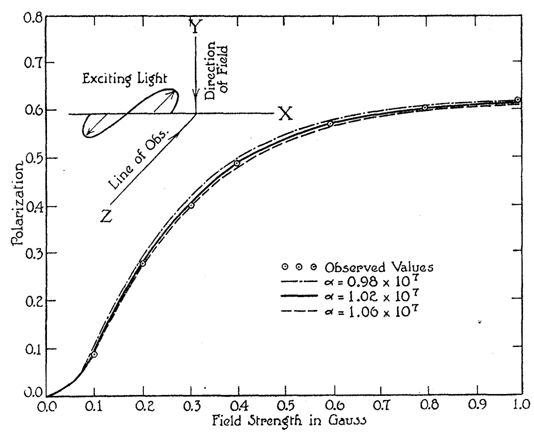

Fig. 3.

tion between polarization and intensity of magnetic field is given by the equation.

$$P=\frac{15}{23+2(2\alpha mc/geH)^2}$$

where α is the damping constant or reciprocal of the mean life of the excited atom. The three curves of Fig. 3 are drawn for values of α of 0.98, 1.02, 1.06×10^7 sec.$^{-1}$ respectively, and it is evident that its value is very nearly 1.02×10^7 sec.$^{-1}$, as given by Wien[8] from canal-ray experiments but differing somewhat from that of von Keussler[2] who obtained 0.88×10^7 sec.$^{-1}$ from his curve similar to Fig. 2 above.

The reason for the discrepancy between the writers observations and those of von Keussler is not evident. There are three possibilities, (a) error in measurement of polarization, (b) error in measurement of magnetic fields, (c) a real difference whose explanation might be sought in different relative intensities of the hyperfine structure components. Referring to (a) it might be said that von Keussler used a photoelectric method of measuring polarization and the writer the Cornu method mentioned above. There seems no

[7] Observations made in this laboratory using a Lummer-Gehrcke plate indicate that the mean life for these components is the same.

[8] Wien, Ann. d. Physik **73**, p. 483 (1924).

possibility of a systematic error in either method of the magnitude required to account for the difference. In fact under similar circumstances of excitation the same initial values of polarization are observed.

The possibility of error in the value of the magnetic field was eliminated by using two sets of Helmholtz coils. Results obtained with the two were in complete agreement. The ammeters used in measuring the current were checked against standard instruments.

There remains the third possibility. This would require that the values of $geH\tau/2mc$ should not be the same for the three central hyperfine structure components, so that different relative intensities of these components might give rise to different "average" values of τ. As stated in note 7 this seems improbable.

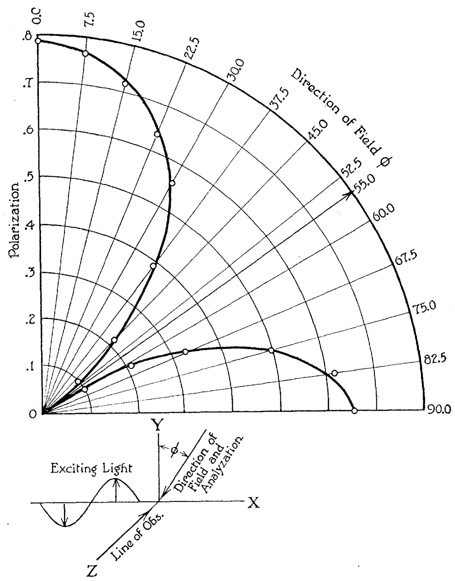

Fig. 4.

It might be pointed out that the displacement of the curve in Fig. 3 for a small change in α is greater than that of Fig. 2, in the range of polarization from 25 to 55 percent where the measurements of polarization are the most accurate.

The curve in Fig. 4 represents the variation of polarization for the various orientations of a fairly intense field (100–200 gauss). Here again the observed values are seen to lie quite well on the curve given by the equation and the angle of zero polarization[9] is 55 within a rather small experimental error.

$$P=\frac{7.5\cos^2\phi-3.75\sin^2\phi}{9.5\cos^2\phi+5.75\sin^2\phi}$$

In conclusion the author wishes to express his thanks to Professor A. Ellett for his advice during the progress of the work.

Hall of Physics,
University of Iowa,
April 21, 1928.

[9] Van Vleck, Proc. Nat. Acad. Sci. **11** p. 612 (1925). Also Eldridge, reference 4.