in the mercury cylinder. The results are given in figure 3; but such a gage is much more mobile as a rule than the large gage and the points obtained from washed fringes are merely estimates. The maximum pressures observed, however, do not differ much from the preceding. Thus the average repulsive forces must have decreased as the areas of the cisterns. With these half filled almost no fringe displacement was obtained. This induced me to fill the cistern of the large gage (Fig. 1) to the brim, so that the mercury column was now 10 cm. in diameter and 2 cm. deep. Possibly from the increased inertia or from greater axial symmetry in the repulsive forces, the fringes were now clearer than before and could be followed with less difficulty even at the highest displacements. These, as indicated in figure 4, were more than twice as large as above under the same conditions ($D = 0.5$ cm.). Thus we have now 9.7×10^{-6} atm. per watt, contrasting with 0.25×10^{-6} atm. per watt for the iron-cored coil; and 0.3×10^{-6} atm./watt compared with 0.17×10^{-6} atm./watt for the free coil. The observations are still straggling, due in part to the wabble of such a massive pool of mercury but largely to some thermal discrepancy affecting the gage zero. Moreover, the fringe displacements for no obvious reason tended to oscillate about different means values. The expectation of using the device for rating dielectric constants was therefore abandoned.

APPARENT EVIDENCE OF POLARIZATION IN A BEAM OF β-RAYS

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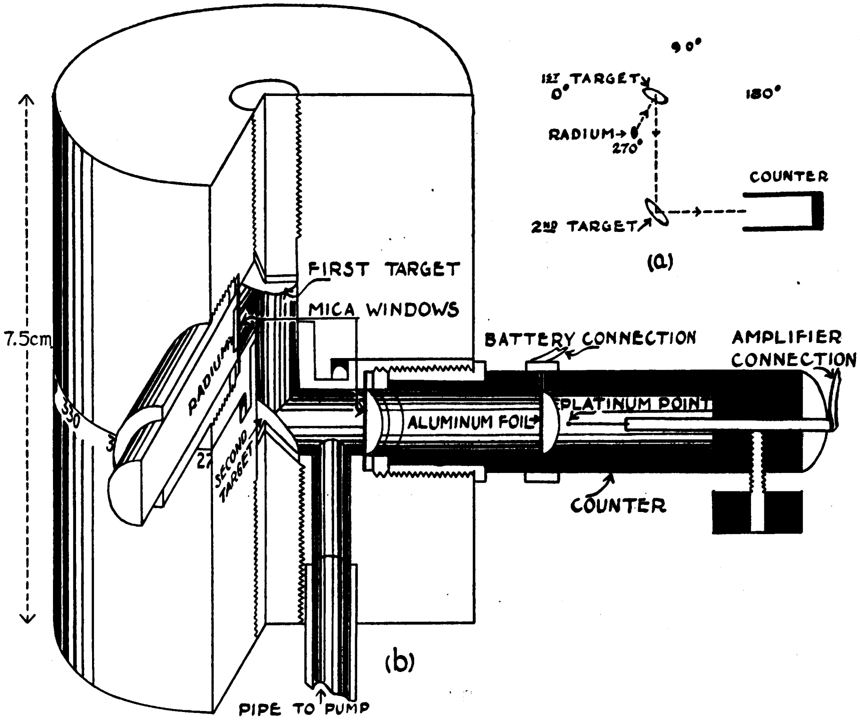
Communicated June 6, 1928

The already classic experiment of Davisson and Germer[1] in which the diffraction of electrons by a crystal shows the immediate experimental reality of the phase-waves of de Broglie and Schrödinger suggested that it might be of interest to carry out with a beam of electrons experiments analogous to optical experiments in polarization. It was anticipated that the electron spin, postulated by A. H. Compton[2] to explain the systematic curvature of the fog-tracks of β-rays, and recently so happily introduced in the theory of spectra by Uhlenbeck and Goudsmit[3] might appear in such an experiment as the analogue of a transverse vector in the optical experiments. This idea has lately been theoretically developed by C. G. Darwin.[4] Experiments in this line were undertaken over a year ago. Since they are soon to be interrupted, it seems advisable to make a preliminary report of the results obtained thus far, although they are somewhat inconclusive in spite of a great accumulation of data.

Since the equivalent wave-length in the wave mechanics of even slowly moving electrons is of the order of that of x-rays, it seemed preferable to attempt an experiment analogous to optical polarization by scattering or absorption rather than by reflection or double refraction. We have been chiefly occupied by an experiment analogous to that in which Barkla demonstrated the polarization of x-rays by double scattering. In our experiment β-particles, twice scattered at right angles, enter a Geiger counter. The relative numbers entering are noted, as the angle between the initial and final segments of the path is varied. For reasons to be mentioned later the angles at which most of the observations have been made are those indicated in figure 1(*a*) as 270° and 90°. The difference between the configurations of the three segments of path at these two angles is the same as the difference between right- and left-handed rectangular axes. The apparatus in its latest form is shown in detail in figure 1(*b*), a quarter-section being supposed removed. Its largest part is a steel cylinder with a cylindrical passage along the axis and two others at right angles to it. The axial passage is closed at either end with a screw plug. Each plug ends in a gold scattering target set opposite one of the radial passages and at 45° to the axes of the two passages at the junction of which it is placed.



A milligram of radium, which is the source of the β-particles, is set in one of the radial passages and the counter in the other. The three passages thus form the three segments of the path of the β-particles. To obtain the required variation in angle between the initial and final segments, the cylinder is made in two parts, so that the upper part, carrying the radium and the first target, can be rotated with respect to the lower about their common axis. The parts fit together at a ground joint with a mercury seal; the two radial passages are closed with mica windows, thin enough to allow the entrance and exit of the β-particles but thick enough to sustain atmospheric pressure; the plugs in the axial passage are sealed in with wax. The cylinder is thus made nearly air-tight and the cavity is kept evacuated by continuous pumping to a pressure at which the mean free path of a β-particle is large in comparison with the length of its path through the cavity. The counting chamber is a hollow ebonite cylinder. It is closed with an aluminum foil, which is kept at a positive potential of about 2000 volts by connection to a storage battery. The ionization which occurs when a β-particle passes through the foil into the chamber produces a discharge between the foil and a platinum point a few millimeters behind it. The point is a platinum wire two mils in diameter ending in a fused knob about six mils in diameter. This point is connected through a high resistance to ground and directly to a four-stage amplifier. The amplifier operates a sensitive relay, which in turn actuates a recording pen on a moving tape. Discharges are produced not only by β-particles but also by photo-electrons ejected from the apparatus by the γ-rays of the radium. The high penetration of these rays makes it impossible to shield against them without interposing so much material that the path of the β-particles would be too much lengthened. Their effect is considerably reduced by making the counting chamber of ebonite, from which comparatively few photo-electrons are ejected. Their number, however, could not be neglected, but there is no reason to expect that it would vary between the two settings at which most of the counts were made.

Although the platinum points described were found the best of several types and materials that were tried, they are far from satisfactory. They usually give inconsistent results after an hour or two of use and have to be replaced. Moreover, the counts obtained with two different points do not agree. For this reason and on account of the uncertainty of the effect of the γ-rays, it seemed inadvisable to attempt counts all around the circle. Attention was given instead to taking counts to test an early observation that fewer β-particles were recorded with the radium at 90° than at 270°. Data are taken as follows. A count is taken at one setting for a definite time (five or ten minutes) and then at the other setting for an equal time. This is continued usually as long as the counter gives self-consistent results. To offset the effect of small gradual changes in the characteristics of the counter and in the voltage of the battery, the count at one setting is compared with the counts immediately preceding and following it at the other setting. Thus, for example, from eleven counts five values are obtained for the ratio of the count at one setting to the count at the other. The mean of these values is taken and the probable error computed in the usual way. It is these means and probable errors that are given in the following table. It must be admitted that the probable error in many cases is reckoned from too few values to give it great validity. The table shows the results of nineteen sets of data.

$\frac{\text{Count at } 90°}{\text{Count at } 270°}$	..	..	..	..	0.76	0.90	0.94	0.87	0.98	1.03
$\frac{\text{Count at } 90°}{\text{Count at } 0°}$	0.78	0.62	0.65	..	..	..	..	..	..	..
$\frac{\text{Count at } 0°}{\text{Count at } 270°}$	..	..	..	0.87	..	..	..	..	..	..
Probable error	0.01	0.02	0.01	0.02	0.01	0.07	0.01	0.02	0.01	0.03
$\frac{\text{Count at } 90°}{\text{Count at } 270°}$		1.03	0.91	0.95	0.99	1.01	1.06	1.05	0.55	0.91
Probable error		0.02	0.02	0.05	0.03	0.04	0.05	0.02	0.05	0.03

It will be noted that of these results a large part indicate a marked asymmetry in the sense already mentioned. The rest show no asymmetry beyond the order of the probable error. The wide divergence among the results calls for some explanation, and a suggestion to this end will be offered later. Meanwhile a few remarks may be made on the qualitative evidence of asymmetry. Since the apparatus is symmetrical in design as between the two settings at 90° and 270°, the source of the asymmetry must be looked for in an accidental asymmetry in construction or in some asymmetry in the electron itself. The following possibilities may be suggested in the former case. The radium and the point in the counter were doubtless not exactly centered. But they were removed and replaced repeatedly in the course of the observations, and it seems unlikely that their accidental dislocations could be so preponderantly in one direction as are the observations. Any effect due to this cause could be offset by turning the counter and the rod that carries the radium through 180°. The apparatus with which these data were obtained was not designed to make this convenient, but in the latest apparatus these rotations can be made without disturbing anything else. The results thus far obtained with this apparatus do not lead us to believe that this factor is effective. There was doubtless some asymmetry in the targets as regards their orientation and surface condition. These also were several times removed and replaced after their surfaces had been freshly filed bright. A magnetic field inside the cavity due either to the slight penetration of the earth's field through the steel walls or to an accidental magnetization of the cylinder itself would introduce an asymmetrical factor. It seems highly unlikely, however, that any deflection so caused could be great enough to produce effects of the magnitude observed. It seems possible, on the other hand, that a spinning electron might be oriented by even a weak field by a kind of space quantization and that this orientation might combine with the scattering to produce the observed asymmetry. This explanation, of course, assumes a polarity in the electron as definite as that required to explain the observations as due to double scattering. Of the same sort is the supposition that the beam of β-particles undergoes a polarization in passing through the mica windows, similar to the polarization of light in passing through a tourmaline crystal. This effect was in fact looked for carefully in an experiment auxiliary to the present investigation but it was not found.

It should be remarked of several of these suggested explanations of the observations that their acceptance would offer greater difficulties in accounting for the discrepancies among the different results than would the acceptance of the hypothesis that we have here a true polarization due to the double scattering of asymmetrical electrons. This latter hypothesis seems the most tenable at the present time. The discrepancies observed we ascribe tentatively to a selective action in the platinum points, whereby some points register only the slower β-particles. Observations in apparent agreement with this assumption have recently been made by N. Riehl.[5] It is necessary to suppose further that the polarization is also selective, the effect being manifest only in the faster β-particles. In support of this it may be remarked that a few observations we have just made seem to show that asymmetry is more consistently observed when a piece of celluloid or cellophane is placed in front of the counter to stop the slower β-particles. Perhaps the simplest assumption here is that only β-particles which are scattered without loss of energy show polarization.

We have made no attempt at a theoretical treatment of double scattering beyond a consideration of the question whether the results here reported are of an asymmetry of higher order than what might be expected of a spinning electron. The following suggestion is then offered not at all as a theory of the phenomenon but merely as a remark on the geometry of the experiment. If it be supposed that the spin vector of a moving electron is always at right angles to its velocity vector, and that when the electron is scattered at right angles its new velocity vector has the direction of the vector product of its former velocity and spin vectors and its new spin vector has the direction of its former velocity vector, then the observations here described will be qualitatively accounted for.

In closing we wish to acknowledge gratefully our indebtedness, for help and advice in the construction of Geiger counters, to Dr. C. W. Hewlett of the General Electric Company, to Mr. A. E. Loomis of the Loomis Laboratory and to Dr. L. F. Curtiss of the Bureau of Standards. We are under obligation also to Mr. Hermann Beck for his interest and care in the construction of the apparatus used.

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THE SPECTRUM AND STATE OF POLARIZATION OF FLUORESCENT X-RAYS

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Communicated June 11, 1928

A brilliant series of experiments by Barkla and Sadler,[1] begun in 1907, showed the now well-known phenomenon of fluorescent x-rays, excited in the heavier elements when traversed by primary x-rays of shorter wavelength. They identified two series of such fluorescent rays, which they called K and L radiations. With the advent of crystal spectrometry, the Braggs[2] and Moseley and Darwin[3] showed that the absorption coefficients of the lines in the x-ray spectra were the same as the absorption coefficients which Barkla and Sadler had found for their fluorescent radiations, thus identifying the fluorescent K and L series radiations with the characteristic line radiation which comes directly from the target of an x-ray tube. This identification was made more definite when spectra of the fluorescent rays were obtained, which showed the same lines as those present in the direct rays. Such spectra have been published, for example, by Duane and Shimizu,[4] Clark and Duane,[5] Woo[6] and D. L. Webster.[7]

In Sadler's earliest studies of the fluorescent rays,[8] he finds by absorption measurements that under favorable conditions not more than 1 per cent of the secondary rays from a fluorescing radiator are scattered. The spectra of Clark and Duane,[5] however, indicate that with fluorescent radiators of barium, lanthanum, molybdenum and silver, excited by x-rays produced at about 90 kv., less than 4 per cent of the secondary radiation consists of the homogeneous fluorescent rays. Woo's spectra, on the other hand, show