By properly separating the extraordinary Hall effect due to magnetization from the ordinary Hall effect due to a uniform field (the magnetizing force H), a well-behaved Hall constant for ferromagnetics can be measured which should provide considerable information concerning the band structure of ferromagnetics.

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Scattering of 20-Mev Alpha-Particles by Helium

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THE angular distribution of alphas elastically scattered from helium gas has been studied using a photographic method. Twenty-Mev alphas from the cyclotron entered the scattering chamber from a collimating slit system. Scattering angles were defined by a number of radial slots (Fig. 1) cut in an iron ring, each mounting a set of defining slits. Particles scattered through these slits were recorded by their tracks in photographic emulsions placed at known angles behind each slot.

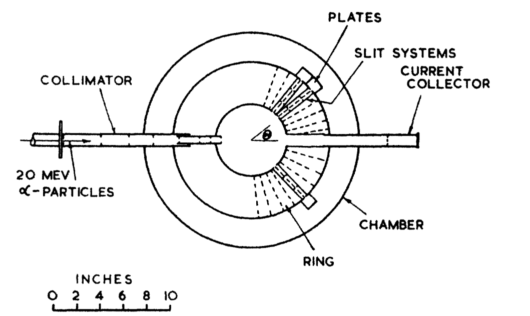

FIG. 1. Schematic of photographic scattering chamber. Angles of scattering are defined by the slits mounted in radial slots cut in the ring (dotted lines indicate positions of slit systems).

The scattering cross section $\sigma(\Theta)$ at any laboratory angle Θ, could be calculated from measurements of slit dimensions, slit distances from the scattering volume, angles of tilt of the photographic plates to the horizontal, the total number of alphas traversing the chamber, and the number of tracks per unit area of plate surface. A noteworthy advantage of the chamber was its dependence predominantly on length measurements which could be made easily and accurately. The number of particles traversing the chamber was determined by collecting the total charge on a Faraday cup connected to a 1.10-μf condenser whose potential was measured with a calibrated quadrant electrometer. The helium gas pressure was obtained from an Apiezon B oil manometer.

The alpha-particle energy was ascertained by measuring the ranges in photographic emulsions of the alphas at each angle of scattering Θ; $E_0=20.0\pm0.3$ Mev.

The data reported here is preliminary only, being based on a single run and with a total track count of only $\sim$7000. Owing to the small alpha-beams produced by the cyclotron; runs were very long, which resulted in trouble from impurity scattering, leakage corrections to the current integrator system, and relatively poor statistics. In proton scattering it is feasible to apply reliable corrections for impurity scattering (air and vapors) based on identifiably different *bona fide* and spurious track lengths. This feature is almost lost in alpha-scattering because of the less favorable mass ratio between scattered and impurity particles.

Table I lists $\sigma(\theta)$, the center-of-mass scattering cross section *versus* center-of-mass angle θ, together with probable errors based on the statistics at each angle. By comparison, other errors which affect the relative cross sections are negligible at most angles. However, absolute values of $\sigma(\theta)$ may be in error by as much as 10 percent. The starred values are very uncertain owing to impurity effects at small angles. (They probably can be taken as upper limits.) Column 4 gives the ratio of observed to Mott cross sections:

TABLE I. Center-of-mass cross sections $\sigma(\theta)$ for 20-Mev alpha-alpha scattering, and ratio to Mott cross sections.

Θ	θ	$\sigma(\theta)\times10^{25}$ cm^2 sterad^{-1}	$\sigma_{obs}/\sigma_{Mott}$
7°	14°	*14.1 ±0.7	1.53
11	22	* 7.7 0.3	4.85
15	30	3.9 0.1	7.82
16	32	3.7 0.1	9.34
21	42	2.00 0.11	12.8
25	50	1.58 0.06	17.3
30	60	1.23 0.08	21.9
35	70	0.92 0.06	22.4
40	80	1.04 0.07	30.4
45	90	—	—
50	100	0.97 0.08	28.4
55	110	1.06 0.08	25.9
60	120	1.19 0.09	21.2

$$\sigma(\theta)_{\text{Mott}}=\frac{4e^4}{E_0^2}\{\operatorname{cosec}^4\Theta+\sec^4\Theta+2\operatorname{cosec}^2\Theta\cdot\sec^2\Theta\cdot\cos(\eta\log\tan^2\Theta)\}$$

$\eta=4e^2/\hbar v=0.282$ for 20-Mev alphas.

As expected, there was no evidence at 20 Mev of inelastic scattering. However, if the alpha-particle has excited states 10 to 20 Mev above ground, an alpha-alpha experiment at 40 Mev could (at least from energy considerations) show inelastic scattering. It is proposed to attempt this with alphas from the Birmingham 60-in. cyclotron.

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** Exposures were made at Washington University, St. Louis, Missouri, in 1949, using the 45-in. cyclotron.

The Discrepancy in the Energy of Annihilation Radiation and the Possibility of Electron-Positron Mass Difference

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THE energies of certain gamma-radiations (Au^{198}, Co^{60}, and annihilation radiation) have been measured with good precision with a crystal spectrometer.[1] Recently, however, it became apparent from measurements on the double focusing spectrometer[2] at this laboratory that there was a discrepancy between the energy of the annihilation radiation measured in terms of the Au^{198} 411-kev line and the value calculated from the Einstein relation $E_0=m_-c^2$ using the best values of the constants.[3]

The comparison of the Au^{198} radiation with the annihilation radiation can be made very accurately because electrons ejected from the L_{III} shell in uranium by the 411-kev radiation have a momentum only 1 part in 1000 less than those ejected from the K shell by the annihilation radiation. The effect of converter thickness is the same for both lines; it is necessary to consider only the effect of the Doppler broadening.

Comparisons were carried out with sources of Au^{198}, Cu^{64}, and Co^{60} mounted in brass tubes to eliminate the continuous beta-spectra. The positrons from the Cu^{64} annihilate in copper or brass. A 0.7-mg/cm^2 uranium converter was used and the resolution set at 1.6×10^{-3}. For comparison, window curves for thorium I, L, and X lines at 1750, 2603, and 10.000 $H\rho$, respectively, were also taken. These were used to correct for the converter effects.

The shapes of the Au^{198} UL_{III} and Cu^{64} U_K lines, shown as curves A and C, respectively, in Fig. I, were obtained by a suitable averaging of the individual curves. The Au^{198} UL_{III} line is considered the effective window since it is the response of the instrument to a mono-energetic gamma-ray. The true instrument window curve (transmission curve of the spectrometer for isotropic mono-energetic electrons) obtained from the ThL line is shown also on curve A. Curve B is the assumed electron momentum distribution arising from the Doppler broadening of the annihilation line; the points on curve C represent the form predicted by folding curves A and B together. The reference lines on curves A and C represent the true line positions when window asymmetry and converter effects have been eliminated. Each experimental curve was fitted to the average line profile and the position of the reference line was recorded on the R scale; these are the values tabulated in Table I. The potentiometer values given there are directly proportional to the momentum ($H\rho$) values of the lines.

TABLE I. Potentiometer resistance values of the various photo-lines used in this work.

Run	Au^{198} U_K	Au^{198} U_{L_I}	Au^{198} $U_{L_{III}}$	Cu^{64} U_K	Co^{60} U_K (1.33-Mev line)
1	7332.0	8709.0	8776.0	8786.0	19385.6
2	7332.7	8709.6	8775.7	8785.7	19384.4
3	7333.0	8709.4	8775.2	8784.9	19384.9
4	7330.8	8708.5	8775.4	8785.8	
5		8709.3	8774.0	8785.8	
6		8709.5			

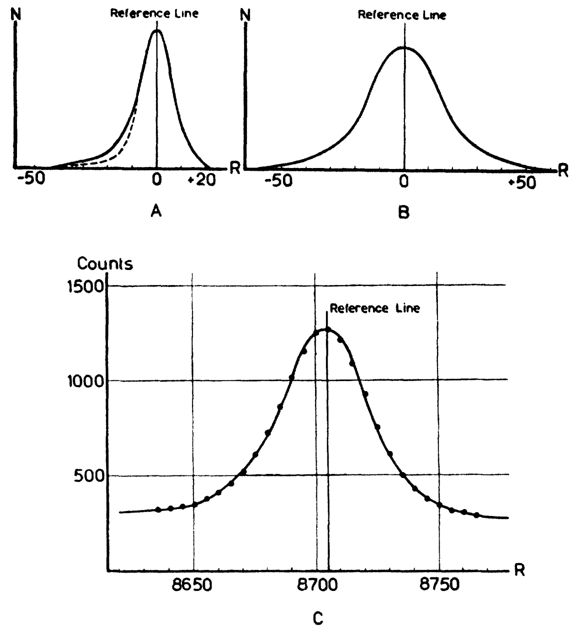

FIG. 1. Folding of Au L_{III} line with an assumed annihilation line momentum distribution to correct for Doppler broadening in the annihilation line. Curve A is the line shape of the Au L_{III} line (dashed curve is the instrument window when no converter is used). Curve B is the assumed momentum distribution of the photo-electrons. Curve C is the observed annihilation line. The dots represent the points predicted by the folding. The reference line gives in each case the true line center.

The energy of the annihilation radiation can be calculated if the energy difference $K-L_{III}$ in uranium is known. This is just the energy of the $K\alpha_1$ line of the x-ray spectrum; its value is calculated from the wavelength given by Cauchois and Hulubei[4] to be 98.42 kev. The small momentum difference between the two lines is equivalent to 0.73 ± 0.04 kev; hence, the difference between the Au^{198} and annihilation radiation energies will be 99.15 ± 0.04 kev.

The directly measured energy of the Au^{198} gamma-ray is 411.2 ± 0.1 kev.[1] We have tried to check this value in two ways.

A comparison was made between the Au^{198} UL_{III} line and the U_K line of the 1.33-Mev Co^{60} gamma-ray. In this case corrections had to be made for the effect of the converter. When one uses the crystal spectrometer value 1.3316 ± 0.0010 Mev for the energy of the Co^{60} line, the energy of the gold gamma-ray becomes $E_{Au}=411.02\pm0.4$ kev.

Finally the energy of the 411-kev line was measured independently by measuring the U_K and UL_I lines. These data together with the energy difference between them (from the x-ray data) permit one to calculate[5] the energy of the gamma-ray to be: $E_{Au}=411.52\pm0.4$ kev. The effect of the converter was eliminated in all cases by an unfolding procedure.

If we weight these three measurements according to their assigned limits of error, the mean energy of the gold line is $E_{Au}=411.22\pm0.10$ kev. Then the value of the annihilation gamma-ray energy, E_A, becomes $E_A=510.37\pm0.14$ kev. The value of m_-c^2 is[3] $E_0=510.96\pm0.02$ kev. Hence the difference $E_0-E_A=0.59\pm0.16$ kev, based principally on the Au^{198} crystal value, is quite probably real.

The crystal spectrometer value of E_A is 510.68 ± 0.1 kev;[1] this does not agree with the present determination. We were informed that this measurement is being repeated; for this reason, and because the Au^{198} crystal spectrometer measurement which we have used is the average of three separate determinations made over a period of two years with two different crystals, we prefer to keep the two results separate. In our work the effects of varying sensitivity and sloping background under the lines are insignificant. The only error which could be large enough to account for the discrepancy may be a systematic calibration error of the crystal spectrometer, but this seems unlikely.

If the effect is real, some mechanism for the disappearance of 1180 ev of energy must be found. The results of DeBenedetti, *et al.*,[6] indicate that the annihilation process should release the total mass energy of the positron and electron except for a small second-order effect from the Doppler broadening. If the Einstein law for the equivalence of mass and energy is incorrect, then the same law applied to moving particles which we used to determine independently the energy of the Au radiation is probably also incorrect. Unfortunately, our data on this point are not better than 1 part in 1000, but in no case have the predictions of the special relativity theory applied to atomic systems been shown to be incorrect.

The most interesting possibility is that the mass of the positron is not equal to the mass of the electron measured by other experiments. The result of our measurements indicates that, under this assumption, the positron must be lighter than the electron by 0.0023 electron masses; the crystal spectrometer annihilation energy value results in a mass difference of 0.001 electron masses. DuMond has communicated to us during the course of this work that he has been examining this question in connection with his re-evaluation of the atomic constants. A direct comparison of the e/m ratios for positron and electron is the most reliable method of answering these questions which are of extremely great theoretical significance.

The details of this investigation will be published in the *Arkiv för Fysik.*

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