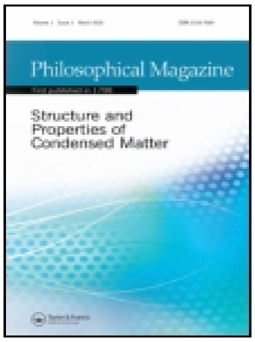

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Circular polarization of γ-rays: Further proof for parity failure in β decay

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giving D' within one order of magnitude between 800 and 1300°C. The ratio of grain-boundary/volume activation energy is $0{\cdot}77 \pm 0{\cdot}13$, which is reasonable.

$D^{1/2}/\delta D'$ in 1 atmos. argon ($<10^{-2}$ mm Hg oxygen) (see figure) was smaller than in 1 atmos. oxygen by up to an order of magnitude between 800 and 1300°C. The fractional excess zinc content of some of our sintered material at 1300°C, measured by a chemical method developed in this laboratory (Allsopp 1957), changed from 3×10^{-6} in 1 atmos. oxygen to 2×10^{-5} in 1 atmos. argon, suggesting a connection between $D^{1/2}/\delta D'$ and composition. Since composition might be expected to affect D more than D', the present results imply that *under our conditions* D may decrease with increasing excess zinc. This picture is less easily reconciled with the commonly assumed model of zinc oxide containing interstitial zinc than with a model involving only anion and cation vacancies.

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Circular Polarization of γ-rays : Further Proof for Parity Failure in β Decay

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LEE and YANG (1956) suggested several experiments for testing the conservation of parity in weak interactions. Two of these have been performed (Wu *et al.* 1957, Garwin *et al.* 1957‡) and have shown that parity is not conserved. Results of a third experiment (thought impracticable by Lee and Yang) are reported here. They confirm the expectation that the γ-rays emitted after β-decay at an angle θ relative to the β-particle should show circular polarization proportional to $\cos\theta$.

† Permanent address: Physikalisches Institut, Erlangen, Germany. This work was performed during a visit to the Cavendish Laboratory.

‡ The author would like to thank Dr. D. H. Wilkinson for providing preprints of these papers and for other valuable information.

Circular polarization of γ-rays can be detected through the Compton scattering by polarized electrons in magnetized iron. Of the three possible experimental arrangements [transmission (Gunst and Page 1953), back scattering (Clay and Hereford 1952) and forward scattering (Wheatley *et al.* 1955)], forward scattering seemed most favourable here.

The scattering cylinder (see figure) was thick enough ($\frac{1}{2}$ in.) to make the scattering by the magnetizing coil negligible. The mean scattering angle was about 55° which is the optimum for a quantum energy of 1·28 MeV. The effect is not smeared out appreciably by the geometry used. No influence of the stray field on the electrons was observed. β–γ coincidences were counted on a standard fast–slow circuit (resolving time 0·1 μ sec). Pulse height selectors in the slow circuits allowed discrimination against back-scattered γ-rays, annihilation radiation and slow β-particles. Random coincidences could be counted by inserting a delay of about 0·5 μ sec in the β-line.

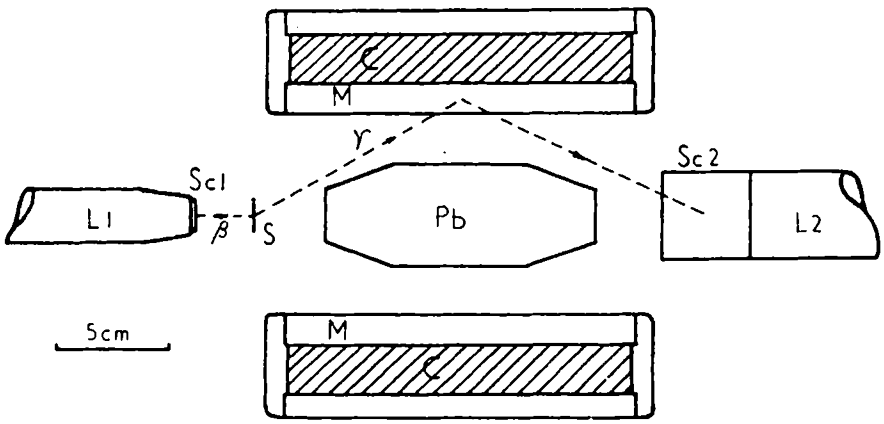
E and *P* expressed as parts per hundred

—	E for $\theta=180°$	P	α Exper.	α theor.	E for $\theta\sim 90°$
^{60}Co	+2·16 ±0·36	+26 ± 4	−0·41 ±0·07	−1/3	+0·67 ±0·49
^{22}Na	−2·33 ±0·52	−28 ±6	+0·39 ±0·08	+1/3	−0·80 ±0·76

The magnetic field was reversed every 5 minutes in order to eliminate drifts in the coincidence resolution. Any variations in detection sensitivity—in particular those caused by the reversal of the magnetic stray field (change of single counting rates $\lesssim 1\%$)—were eliminated by forming R, the number of coincidences divided by the product of the single counts. Let us define the polarization effect $E=2(R_1-R_2)/(R_1+R_2)$ where R_1 and R_2 refer to the magnetization pointing toward and away from the source, respectively. The observed effects at 180° are shown in the first column of the table. ^{60}Co and ^{22}Na were chosen because they have allowed β-transitions with $\Delta J=1$, which should give maximum effect. ^{60}Co emits two γ-rays in a 4–2–0 cascade; in that special case the polarization of the second γ-ray is the same as that of the first (Tolhoek and Cox 1953). Hence the results can be discussed as if Co^{60}—like ^{22}Na—emitted only one γ-ray.

The polarization of the γ-rays is shown in the second column, computed from $E=2fP|\sigma_p/\sigma_0|$, where f is the fraction of oriented electrons in the iron (0·08 at the measured flux density of 20 000 gauss) and σ_p and σ_0 are the polarization-dependent and independent parts, respectively, of the differential Compton cross section ($\sigma_p/\sigma_0=0·52$ for the geometry used).

As a check, some measurements were done at 90°. A small effect (of the order of the statistical error) was found (column 5); actually the average angle was somewhat larger than 90°. On counting random coincidences, no effect greater than the statistical error ($\sim 1\%$) was observed.



Sc1 β-counter (plastic scintillator), Sc2 γ-counter (NaI(Tl)—crystal), L1 and L2 Perspex light guides, S source, M cylindrical magnet with magnetizing coil C, Pb lead absorber.

Calculations by Skyrme (private communication†), based on the two-component theory give $P = \alpha(v/c) \cos\theta$, where α depends on the type of the β- and γ-transition (and is zero for pure Fermi interaction). Theoretical values of α are given in column 4 of the table.

The experimentally determined sign for ^{60}Co fits the experiment of Wu *et al.* The different signs for ^{60}Co and ^{22}Na prove that the antineutrino emitted together with a negatron has the opposite screw sense from the neutrino which accompanies the positron decay. The experimental values of α are somewhat higher than the theoretical ones but the deviations are within the experimental errors.

Acknowledgments

I am very grateful to Professor O. R. Frisch for enabling me to perform this experiment and for his continued interest and helpful suggestions, and to many colleagues of the Cavendish Laboratory, in particular Dr. S. D. Bloom for lending me the coincidence circuit and for discussions on the electronics. My stay in England was made possible by a grant of the German Ministry of Atomic Affairs.

† I am indebted to Dr. Skyrme and Dr. Mandl for giving me the results of their calculation before publication, and for helpful discussions.

Note added in proof:—In the meantime, ^{24}Na (allowed transition, $\Delta J=0$) has been investigated; only a small asymmetry $E=+0{\cdot}56\%\pm0{\cdot}38\%$ was found. The thoery (K. Alder, B. Stech and A. Winther, private communication) predicts a large asymmetry except for practically pure Fermi or Gamov–Teller transitions; our result means that

$$C_T^2|M_{GT}|^2/(C_T^2|M_{GT}|^2+C_S^2|M_F|^2)$$

is either $>99\%$ or $<2\%$. In cases where both interactions are present in comparable amounts it would be possible to find the relative sign of C_S and C_T. I wish to thank D. J. Chandlin for helpful discussions.

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The Weak Lines in the Radium D Gamma Spectrum

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PRIOR to 1939 the decay of radium D (^{210}Pb) was regarded as a simple and well understood β-decay to the 46·5 kev level of ^{210}Bi (the β_{46} transition). However Lee and Libby (1939) showed that only about three-quarters of the disintegrations follow this mode, and this prompted re-examination of the RaD γ-spectrum. Results reported between 1939 and 1954§ showed a number of weak lines, summarized by Wu *et al.* (1953) as follows.

Energy (kev)	46·5	42·6	37±0·5	31±0·8	23·2±0·6	16·1±0·4	7·3±0·7
Intensity %	2·8±0·6	0·2±0·1	0·2±0·1	0·4±0·2	~1	—	~10

Wu succeeded in showing that the lines at 7·3, 16·1 and 23·2 kev originated from secondary, atomic processes, but no conclusion was offered on the 31, 37 and 42·6 kev lines. Ignoring these, a decay scheme

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§ The summarized results of 16 papers in this period are tabulated by Fink *et al.* (1956).