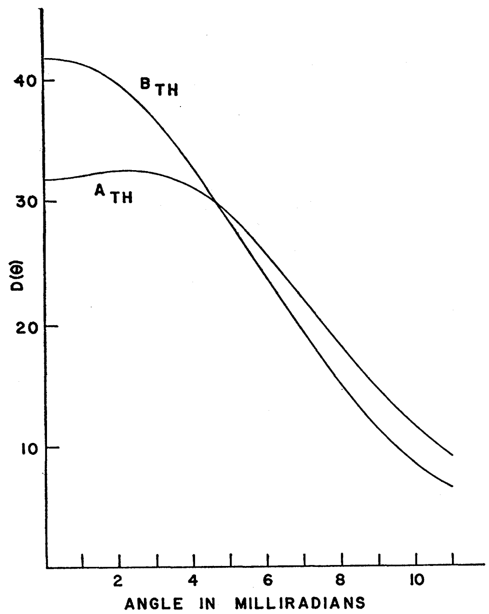

FIG. 3. Theoretical curves representing $D(\theta)$ for oriented single crystal (A_{Th}) and for polycrystalline graphite (B_{Th}).

counting rates and were not normalized in any way; their areas are equal to within 1%.

According to the theory, if the slits are parallel to the z axis and $\pi-\theta$ is the angle between the two slits as observed from the source, the angular distribution should be

$$D(\theta)=\int\int|\chi(p_x,p_y,mc\theta)|^2dp_xdp_y. \qquad (3)$$

To compute this integral, the molecular orbital approximation was made for the trigonal σ bond and the single atom $2p_z$ function was used for the π band.[6] Slater atomic wave functions were used. If the positron wave function is taken to be a constant, but annihilation with the $1s^2$ electrons is neglected, then only the momentum distribution curves for the σ and π electrons are important. That annihilation with the $1s^2$ electrons does not occur is in accord with the good experimental parabola obtained for lithium,[7] corresponding to annihilation with $2s$ electrons only. The distribution, $D_\sigma(\theta)$, of the c-axis component of the momentum for one σ electron (averaged over all directions in the hexagonal plane) is a usual bell-shaped curve. The π electrons, on the other hand, have bimodal distributions D_π, with $D_\pi(0)=0$. This is still true even when Bloch wave functions are used for the π electrons. When the distributions are added $(3D_\sigma+1D_\pi)$, the final distribution is broader than for the polycrystal, but not bimodal. Since the σ bond has been computed more accurately, it might be thought that this is due to too broad a D_π. In Fig. 2 the experimental curve is shown; the theoretical $3D_\sigma$ subtracted from it gives an "experimental" D_π which is compared with the theoretical D_π. The area of the experimental D_π is indeed about $\frac{1}{3}$ of the theoretical $3D_\sigma$. This explanation has the disadvantage, however, that it would make the $3D_\sigma+D_\pi$ distribution in the polycrystal even narrower than that predicted by Coulson and Duncanson,[8] and their distribution is already narrower than the experimental Compton profile. (The Compton profile has a contribution from $1s^2$ also, but this does not alter the argument.)

To a certain extent, therefore, the positron must be making both σ and π distributions narrower, and we should not regard the D_σ as much better than the theoretical D_π. The positron may also weight the π electrons preferentially. This is also suggested by the fact that Kirkpatrick and DuMond[9] did not observe a difference in Compton profile between single and polycrystalline graphite. We show in Fig. 3 the theoretical distributions with areas in the ratio $\pi/\sigma=1.82/2.18$. This ratio gives the correct shapes, but the distributions are too broad. A further theoretical study of the correct positron wave function in graphite would therefore be needed before a better fit with experiment could be expected. We thank Dr. D. E. Soule of the National Carbon Company, for kindly supplying us with the graphite crystal.

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Test of Neutrino—Antineutrino Identity*

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NEW mass spectroscopic data[1] for the atomic masses of Nd^{150} and Sm^{150} bear on the results of a double-beta-decay search using Nd^{150} as it relates to the question of the identity of neutrinos and antineutrinos.[2] We have accordingly re-evaluated the expected and extreme mean lives for comparison with the experimental results with the conclusion that the previous inference as to the inapplicability of the Majorana hypothesis (neutrino identical with antineutrino) stands. The quantitative argument follows: the available kinetic energy of the emitted neutrino, assuming no net neutrino emission in accordance with the Majorana hypothesis, is given by Johnson and Nier as 3.65 ± 0.10 Mev. (We previously used the more favorable value 4.4 ± 0.8 Mev). For this new energy figure a reasonable value for the mean life is 4×10^{15} years, an extreme value is 1.9×10^{18} years.[3] These lifetimes are to be compared with the experimental result of $>4.4\times10^{18}$ years, a limit derived by considering the count rate associated with one standard deviation from a smoothed curve of count rate *versus* energy.[2]

As pointed out by Tiomno,[4] it is possible to build a "mixed" theory in which double beta decay is unaccompanied by neutrino emission, and yet have the neutrino obey the Dirac equation. In this case an observably short lifetime for β decay could have an ambiguous interpretation. Such a theory is restricted independently of the phenomenon of double beta decay by the negative experiment of Davis[5] in which an appreciable amount of such an admixture of neutrinos and antineutrinos from the decay of neutron-rich isotopes would have produced a positive result.

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Evidence for Circular Polarization of Bremsstrahlung Produced by Beta Rays

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We have investigated the degree and sense of circular polarization of bremsstrahlung produced by β^- rays. Near the high-energy end of the spectrum we find that the photons are almost completely circularly polarized, with their spin antiparallel to their direction of propagation.

The question of parity conservation in weak interactions, raised by Lee and Yang,[1] has been partially answered by recent experiments which show that parity is not conserved in interactions involving neutrino emission.[2–4] The two-component neutrino theory[5–7] can account for these results in a natural manner. From this theory it follows that β rays are polarized longitudinally, and if time-reversal invariance is assumed the polarization is found to be $\pm v/c$, where the plus sign is expected for positrons and the minus sign for negative electrons.[7–9] The existence of a polarization compatible with these ideas has recently been demonstrated for both electrons[10] and positrons.[11]

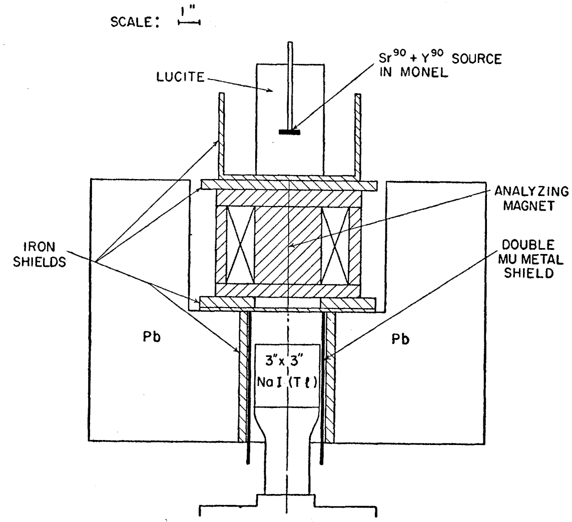

Fig. 1. Arrangement for analyzing degree and sense of circular polarization of bremsstrahlung from β^- source.

It appeared to us worthwhile to investigate whether the longitudinal polarization of the β rays will in turn give rise to a circular polarization of the bremsstrahlung which they produce. To search for such an effect, we used a source of $Sr^{90}+Y^{90}$ in equilibrium. The decay scheme of this source is well known.[12] High-energy β^- rays are emitted from the decay of Y^{90} (maximum energy = 2.24 Mev, $(v/c)_{max}=0.98$; no γ rays have been reported). The source, kindly lent to us by the Medical Research Department of this Laboratory, had an intensity of 120 mC; it was enclosed in Monel, $\sim$100 mg/cm^2, and contained in a thick Lucite cylinder which absorbed all β rays. For such a source assembly, most of the high-energy bremsstrahlung originates in the Monel which has $Z_{eff}\approx28$ (60% Ni, 33% Cu, 6.5% Fe). Only a small fraction consists of internal bremsstrahlung from the source and of external bremsstrahlung produced in the Lucite.[13]

The principle of the analysis of the circular polarization of x-rays is based on the existence of a spin-dependent part of the Compton cross section, as is described in detail by Gunst and Page.[14] The analyzer consisted of a cylindrical electromagnet, which could be magnetized to saturation either parallel or antiparallel to the photon direction (see Fig. 1), thus polarizing 2 out of the 26 electrons of the iron atoms.