which occurred near the front surface of the carbon deposit, the particle momentum is 3.73×10^5 gauss-cm. This leads to $Q=-4.41$ Mev for the inelastic scattering process, which compares favorably with figures quoted elsewhere[1] for the energy (relative to the ground state) of the lowest well-established excited state of C^{12}. The ratio of total intensities for the inelastic and elastic groups is roughly 2.0. No evidence was found for lower excited states of C^{12}.

* Assisted by the joint program of the ONR and AEC.

[1] W. F. Hornyak and T. Lauritsen, Revs. Modern Phys. **20**, 191 (1948) have reviewed previous studies which lead to knowledge of the excited states of C^{12}.

The Angular Correlation of Photo-Electrons Ejected by Annihilation Quanta*

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IT was first pointed out by Wheeler[1] that selection rules require that the polarization planes of two quanta emitted in the annihilation of slow positrons be orthogonal. A number of workers[2] have verified the expected cross polarization through coincidence detection of the quanta scattered from antiparallel beams of annihilation radiation at various azimuth angles. These data yield an asymmetry in the coincidence rate as the relative azimuthal orientation of the detecting counters is varied, the preferred scattering being in the planes containing the radiation beams and the electric vectors of the quanta.

Pryce and Ward[3] have suggested that the relative polarization states also could be determined through observation of the photo-electrons ejected by the quanta at various azimuths. In addition to providing a check on the results obtained by detection of the scattered quanta, this method yields information which was previously lacking on the directional distribution of photo-electrons produced by polarized quanta of relatively high energy (0.51 Mev).

By means of the scheme depicted in Fig. 1 the suggested experiment has been performed. A source of positrons (Cu^{64} or Na^{22}) sealed in an aluminum capsule was placed at the midpoint of a $\frac{3}{8}$-in. hole drilled through a 7-in. Pb cylinder. The beams of annihilation quanta emerging as shown impinged upon two thin wall Pb cylinders of $\frac{1}{4}$-in. diameter. Photo-electrons ejected in planes perpendicular to the radiation beams were detected by two end window G-M counters.

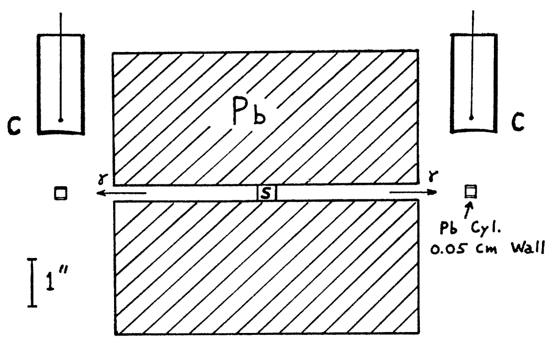

FIG. 1. Schematic drawing of apparatus showing the positron source (*S*), counters (*C*), and the thin wall Pb scatterers.

An aluminum absorption curve taken with one of the counters indicated a photo-electron component with end point at 0.51 Mev plus a gamma-ray background. The photo-electron counting rate with zero absorber (end window only) was approximately one-third the total rate. Compton electrons ejected at the minimum angle θ accepted by the finite half-span of the counter (20°) were of insufficient energy to penetrate the end window, and hence did not contribute to the observed counting rate. The majority of the background gamma-rays apparently were those penetrating the large Pb absorber rather than those scattered from the main radiation beams by the thin wall cylinders. This followed from the observation that, with a given orientation of the two counters, the coincidence rate dropped to approximately the cosmic-ray shower plus accidental coincidence background upon insertion of sufficient aluminum to absorb the 0.51-Mev photo-electrons. This apparent suppression of the gamma-gamma-coincidences was due to the fact that the ratio of photoelectric to Compton scattering cross sections for 0.51-Mev gamma-rays in Pb is about 1.3; to the small amount of material presented by the thin wall cylinders; and to the low detection efficiency for gamma-rays incident upon the end windows.

In cases where Na^{22} was employed, a possible contribution to the coincidence rate was present due to the 1.3-Mev gamma-ray following the beta-transition. The probability of observing these gammas in coincidence with annihilation quanta was small, however, since the nuclear gammas are presumably spherically symmetrical in directional distribution, while the relative emission direction of annihilation quanta is $\pi\pm 1/137$ radians.[4] This argument was supported experimentally by agreement between the Cu^{64} and Na^{22} data.

The experiment proper consisted in the observation of the coincidence rate as a function of the minimum relative azimuthal orientation of the counter axes, $\phi_2-\phi_1$. During the experiment the counters were rotated together through a full 360° in periodic 90° steps to eliminate any geometric asymmetry. The resolving time of the coincidence circuit was 1.7×10^{-7} sec. As a result of the short half-life of Cu^{64} and source strength differences a wide range of total and accidental coincidence rates were involved. Table I shows the collected data with the genuine coincidence rates normalized to a common source strength. The combined accidental, shower, and gamma-gamma-rates were generally less than one-half of the total rate. The significant aspects of the results involve $C_{\perp}/C_{\parallel}$ and are discussed in the following letter. The low coincidence rate at 36° cannot be considered real and is being checked along with other intermediate angles.

TABLE I. Counting rate of genuine coincidences.

$\phi_2-\phi_1$	Coincidences/min	$C_{\perp}/C_{\parallel}$
0°	0.33 ±0.019	1.94 ±0.14
90°	0.64 ±0.020	
36°	0.31 ±0.04	
54°	0.43 ±0.03	

The author is indebted to Dr. P. H. Abelson of the Department of Terrestrial Magnetism for supplying the Na^{22}.

* Supported in part by Navy Bureau of Ordnance.

[1] J. A. Wheeler, Ann. N. Y. Acad. Sci. **48**, 219 (1946).
[2] E. Bleuler and H. L. Bradt, Phys. Rev. **73**, 1398 (1948); R. C. Hanna, Nature **162**, 332 (1948); C. S. Wu and I. Shaknov, Phys. Rev. **77**, 136 (1950).
[3] M. H. L. Pryce and J. C. Ward, Nature **160**, 435 (1947).
[4] DeBenedetti, Cowan, Konneker, and Primakoff, Phys. Rev. **77**, 205 (1950).

The Radioactive Decay of I^{131}

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December 11, 1950

SPECTROMETRIC studies have been continued in an effort to clarify the currently conflicting information[1] relative to radioactive emission of I^{131}, now so widely used in medicine. Sufficiently strong samples have been employed to make an exhaustive search for previously unreported gamma-rays, and by successive exposures to determine the half-life associated with each gamma-ray. The upper energy limits of the two components of the beta-spectrum have also been redetermined by a double-focusing magnetic spectrometer.

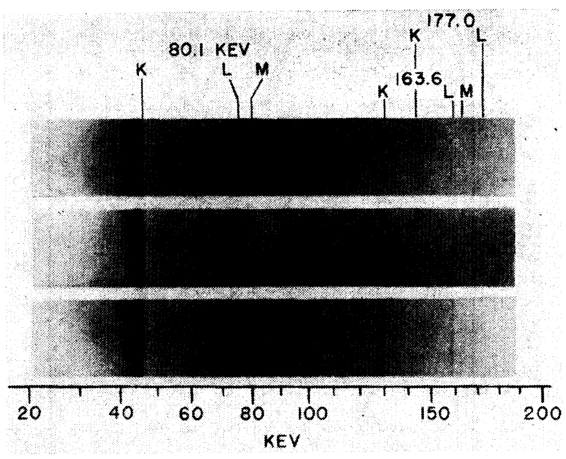

FIG. 1. Successive exposures showing the increased darkness of electron lines due to the 12-day 163.6 gamma-ray.

Using the reported[2] energies of three of the gamma-rays, as measured in a crystal spectrometer by DuMond and his associates, as a calibration standard, the gamma-energies are now found to be: 28.0 (Auger X), 80.1, 163.6, 177.0, 284.1, 364.2, 637, and 723 kev. In every case the conversion electron lines have *K-L* differences characteristic of xenon. The 723-kev gamma-ray, whose conversion electrons were about half as abundant as those for the 637-kev gamma, has not been previously reported.

All gamma-rays except the 163.6 kev are found to decay with a half-life of 8 days. The 163.6-kev gamma-ray has a longer half-life as shown in Fig. 1 and is presumably associated with a 12-day metastable state in xenon as found to exist by Brosi, De Witt, and Zeldes. Figure 1 shows successive exposures for the energy region 20 to 190 kev, with the time of each of the three exposures adjusted so that the electron lines associated with an 8-day half-life should appear equally dark on successive photograms. Electron lines associated with the longer 12-day half-life should then appear relatively stronger in the later exposures. It is evident that the *K*, *L*, and *M* lines for the 163.6-kev gamma-ray do appear to grow stronger relative to the neighboring electron lines of comparable intensity caused by the 177-kev gamma-ray. The upper limits of the two beta-distributions are found to be 600±3 kev and 305±10 kev.

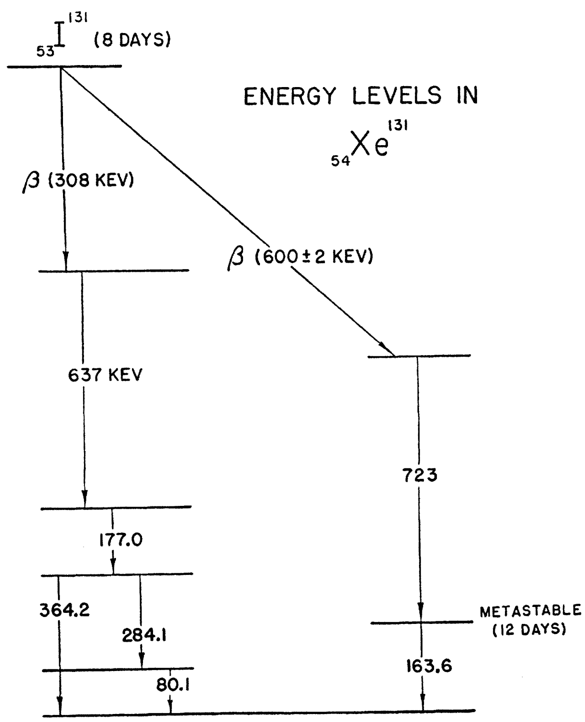

FIG. 2. Possible decay scheme for I^{131}.

It is of interest that these known energies can be accommodated by a level scheme as shown in Fig. 2 in which a branching occurs with exactly the same over-all energy in each branch. While this proposed scheme appears to be highly satisfactory energetically and can also be reconciled with present coincidence measurements, it does not satisfy observations on the relative intensities. The more abundant 600-kev beta-transition is in sequence with the less copious 723-kev gamma-emission and the less intense 305-kev beta is followed by the more intense gamma-emissions. Also, the metastable state in xenon is considered as following the 723-kev gamma-ray since the half-life of this gamma-ray is 8 days. Any alternate scheme must allow isomers of different energy for the parent isotope.

Observations of the beta-spectrum were made by Dr. E. Salmi and will be presented elsewhere.

* This investigation was made possible by the joint support of the AEC and ONR.

[1] G. Tape and J. Cork, Phys. Rev. **53**, 676 (1938); J. Livingood and G. Seaborg, Phys. Rev. **54**, 775 (1938); F. Metzger and M. Deutsch, Phys. Rev. **74**, 1640 (1948); Owen, Moe, and Cook, Phys. Rev. **74**, 1879 (1948); Brosi, De Witt, and Zeldes, Phys. Rev. **75**, 1615 (1949); Cork, Keller, Sazynski, Rutledge, and Stoddard, Phys. Rev. **75**, 1621 (1949); Kern, Mitchell, and Zaffrano, Phys. Rev. **76**, 94 (1949); and I. Feister and L. Curtiss, Phys. Rev. **78**, 179 (1950).

[2] Lind, Brown, Klein, Muller, and DuMond, Phys. Rev. **75**, 1544 (1949).

Magnetic Structure of Magnetite and Its Use in Studying the Neutron Magnetic Interaction

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December 8, 1950

THE interaction of the magnetic moment of a neutron with the atomic magnetic moments existing in magnetic substances has been shown by Bloch,[1] Schwinger,[2] and Halpern and Johnson[3] to give rise to scattering effects comparable in magnitude to those produced by the nuclear short range interaction. This magnetic interaction has been studied experimentally in ferromagnetic substances by means of the so-called single and double-transmission types of experiments for which the most noteworthy and complete descriptions have been given recently by Hughes, Wallace, and Holtzman[4] and by Fleeman, Nicodemus, and Staub.[5] Further studies performed with neutron reflection by magnetized mirrors have been discussed by Hughes and Burgy.[6] We have been investigating the Bragg scattering of neutrons produced by paramagnetic and antiferromagnetic substances and by unmagnetized and magnetized ferromagnetic substances and these have yielded information on the magnetic structure of the samples and on the magnitude and directional properties of the interaction which exists between the neutron's magnetic moment and the atomic magnetic moment.

A study of the magnetic scattering properties of Fe_3O_4 is of interest in that (a) it gives a direct check on the magnetic structure and (b) that its magnetic properties make it very favorable for use in studying the directional properties associated with the magnetic scattering of neutrons. This oxide is a member of the ferrite series and is ferromagnetic. Néel has suggested the magnetic structure to be of *ferrimagnetic* type,[7] that is, that some of the ferrous and ferric ions which make up the lattice are coupled antiferromagnetically. On this picture the balancing of the parallel and antiparallel moments is not complete and Néel has been able to explain quantitatively the resultant ferromagnetism of the lattice. Neutron diffraction studies have been made on several

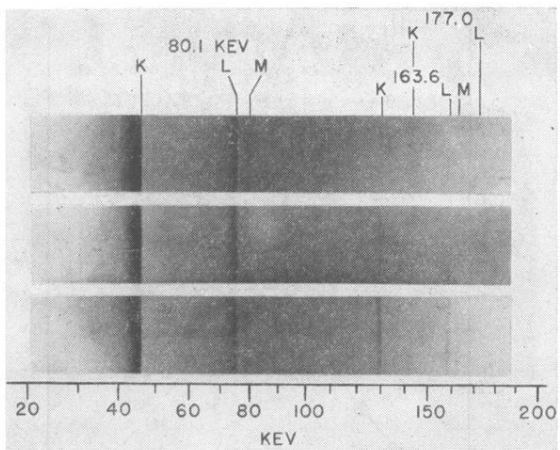

FIG. 1. Successive exposures showing the increased darkness of electron lines due to the 12-day 163.6 gamma-ray.