isomers by Goldhaber and Sunyar[8] has shown that the group of isomers previously identified with $A=4$ ($E4$ and $M3$ transitions) consist really of transitions with $\Delta I=3$ ($E3$ and $M3$ transitions), and that the calculated K/L ratios of Hebb and Nelson[3] for electric transitions with $\Delta I \geq 3$ yield spin changes one unit too high. In the new classification, Cd^{111m}, Cs^{134m}, and Ta^{182m} are $E3$ transitions. These transitions are the slowest of the $E3$ group and in fact are nearly slow enough to be compatible with Weisskopf's $E4$ lifetime formula. The K/L ratios for these transitions clearly

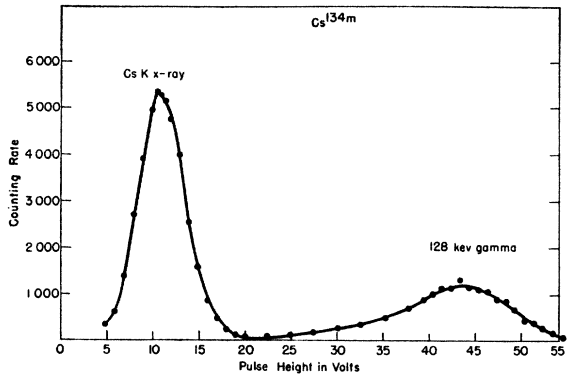

FIG. 1. Pulse-height distribution from Cs^{134m}.

indicate their electric character. An accurate measurement of the internal conversion coefficients will thus decide in favor of $E3$ or $E4$.

Measurements of the conversion coefficients have been made with a scintillation counter using a 1-cm cube crystal of NaI (Tl). A single-channel differential discriminator was used for determining the pulse height distribution. The K conversion coefficient was determined by comparing the intensity of the K x-rays relative to that of the unconverted gamma-ray. The heights of the

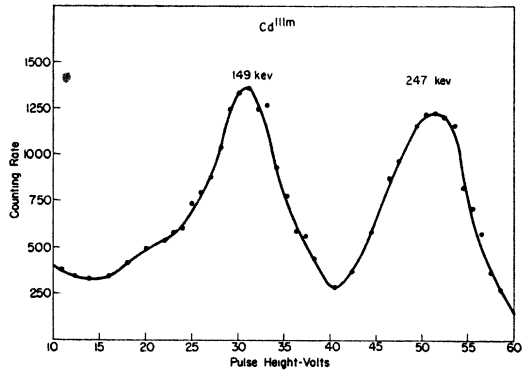

FIG. 2. Pulse-height distribution from Cd^{111m}, showing the unconverted 149-kev and 247-kev gamma-rays.

photopeaks above background give directly the K conversion coefficient when corrections are applied for the following factors: (1) the percent absorption of the radiations in NaI 1-cm thick;[9] (2) the ratio of photoelectric cross section to total absorption cross section,[10] including the effect of Compton scattering by Na in the crystal; (3) the fluorescent yield for the x-rays;[11] (4) the variation of half-width for a photopeak with γ-energy; (5) the change in the fractional acceptance interval, $\Delta E/E$, of the channel with discriminator setting; (6) variation, if any, of the absolute channel width ΔE with discriminator setting. The method has been checked by a measurement of the x/γ-ratio for Te^{123m}. The computed value expected from previous measurements of electron intensities[12] is 0.61, while the measured value is 0.59 ± 0.08.

The sources were prepared by slow neutron bombardment in the Brookhaven reactor. In the case of cadmium, the separated isotope Cd^{110} obtained from Oak Ridge was used.

A typical pulse height distribution from which x/γ-ratios are obtained is shown in Fig. 1 for Cs^{134m}. In Fig. 2 are shown the photopeaks of the 149- and 247-kev gamma-rays of Cd^{111m}, from which the $\gamma 149/\gamma 247$ ratio may be computed. The conversion coefficient for the 247-kev gamma-ray is known,[4] and hence the total conversion coefficient for the 149-kev gamma-ray is determined. The known K/L ratio for this transition[4] allows α_K to be determined. The experimental results are summarized in Table I.

TABLE I. Experimental and theoretical conversion coefficients.

Isomer	E(kev)	Measured α_K	Theoretical α_K[a] $E3$	$E4$
Cd^{111m}	149	x/γ: 1.45 ± 0.4 $>1.5\pm0.3$ $\gamma 149/\gamma 247$: 1.60 ± 0.5	1.4	7.1
Cs^{134m}	128	2.2 ± 0.4	~2.45	~12
Ta^{182m}	180	0.8 ± 0.3	0.69	2.05

[a] See reference 5.

The measurements are compatible only with the conclusion that all of the transitions are of the $E3$ type in spite of their comparatively long lifetime.

* Research carried out under contract with the AEC.
[1] P. Axel and S. M. Dancoff, Phys. Rev. **76**, 892 (1949).
[2] National Bureau of Standards Circular 499 (1950), unpublished.
[3] M. H. Hebb and E. Nelson, Phys. Rev. **58**, 486 (1940).
[4] C. L. McGinnis, Phys. Rev. **81**, 734 (1951). A private communication from Dr. A. C. Helmholz to Dr. M. Goldhaber states that a later measurement by Mr. McGinnis agrees with that expected for an $E3$ transition.
[5] Rose, Goertzel, Spinrad, Harr, and Strong, privately circulated tables.
[6] S. Johansson, Phys. Rev. **79**, 896 (1950).
[7] V. F. Weisskopf and J. Blatt, privately circulated chapter from forthcoming book on nuclear theory.
[8] M. Goldhaber and A. W. Sunyar, Phys. Rev. (to be published).
[9] A. H. Compton and S. K. Allison, *X-Rays in Theory and Experiment* (D. Van Nostrand Company, Inc., New York, 1935).
[10] M. T. Jones, Phys. Rev. **50**, 110 (1936).
[11] Steffen, Huber, and Humbel, Helv. Phys. Acta **22**, 167 (1949).
[12] Katz, Hill, and Goldhaber, Phys. Rev. **78**, 9 (1950).

Disintegration of Sn^{119m}

R. D. HILL
*University of Illinois, Urbana, Illinois**
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EARLIER experiments[1] on the disintegration of Sn^{119m} showed the existence of a strongly converted 69-kev transition, of 250-day half-life, and probably $M4$ character. It was suggested that this transition should be followed by a second transition, probably of $M1$ character.

The first sources proved to be too weak to measure an accurate energy of the first transition or to observe the existence of the

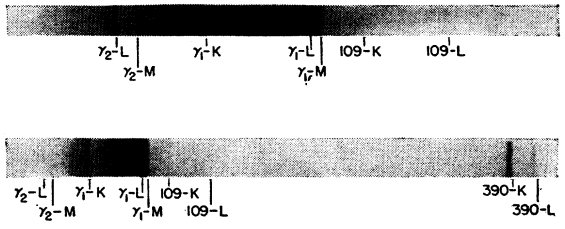

FIG. 1. Conversion spectra of Sn^{119m}. Upper spectrum, 100-gauss magnet. Lower spectrum, 200-gauss magnet. $\gamma_1=65.3$ kev, $\gamma_2=24.2$ kev; 109-kev transition from Te^{125m}, 390-kev transition from In^{113m} (produced from Sn^{124} and Sn^{112} by neutron capture and subsequent decay).

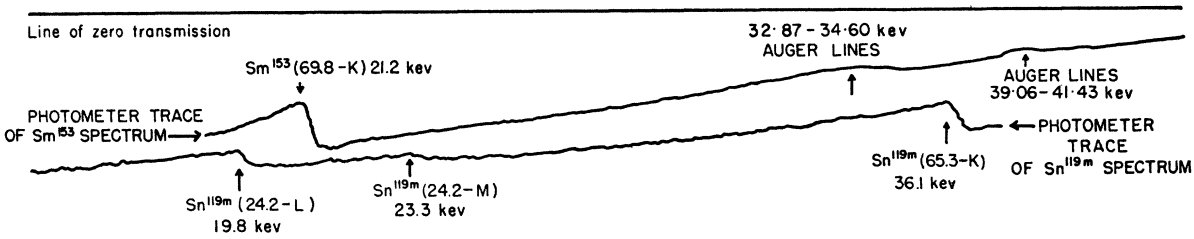

FIG. 2. Microphotometer traces (redrawn) of Sn^{119m} and Sm^{153} spectra in the region from 19 to 42 kev. The similarity of the 19.8-kev line with other conversion lines (e.g., 21.2 and 36.1 kev) and the contrast with Auger lines are exhibited.

TABLE I. Intensities of conversion lines in Sn^{119m} electron spectrum.

Line	24.2-L_I	24.2-M_I	65.3-K	65.3-L_{III}	65.3-M_V
Energy (kev)	19.8	23.3	36.1	61.4	64.8
Density	0.050±0.005	0.020±0.005	0.110±0.005	0.715±0.005	0.205±0.005
Intensity (arb)	5.2	1.2	1.6	3.1	0.8

second. A crude estimate[2] of the slow neutron capture cross section of Sn^{118} for the production of Sn^{119m} was 0.004 barn. Much more intense sources have now been produced by irradiating a Sn^{118} sample (enriched to 91 percent) in a high neutron flux for a period of five months.[3]

Electron spectra of Sn^{119m} taken with 180° magnetic spectrographs are shown in Fig. 1. Two γ-transitions of 24.2±0.5 and 65.3±0.5 kev are observed. The energy of the former is computed on the basis of conversions mainly in the L_I and M_I shells. Also present in the spectrum is the well-known 390-kev γ-transition of In^{113m}, produced from Sn^{112}, which is itself produced from 0.2 percent of Sn^{112}. Although a lifetime check for a period of ~250 days has not yet been made, the 24.2-kev transition is clearly identified as the second transition of Sn^{119m}, since it agrees well with the value of 20±5 kev determined recently for this transition by Scharff-Goldhaber *et al.*,[4] who used scintillation and proportional counters.

Since the conversion lines of the 24.2-kev transition lie within the region of the Auger lines from the Sn and In x-rays, it is important to verify that the 24.2-L and 24.2-M are not Auger lines. (From the intensity of the 390-kev conversion lines it can be shown that the In x-ray intensity, arising mainly from the 110-day K-capture activity of Sn^{113}, is approximately equal to the intensity of the Sn x-rays arising from conversion of the 65-kev Sn^{119m} transition. On this basis also, the capture cross section of Sn^{118} comes out to be 0.003 barn.) It should first be noted that the appearance of the 24.2-L conversion line is different from that of an Auger group. This is clearly shown in Fig. 2, where the photometer traces of Sn^{119m} and Sm^{153} spectra, in similar energy regions, are compared. It is also clear from the intensity analysis that the 24.2-L line is approximately 15 times more intense than that of all the indium Auger lines put together.

Measurement of the intensity of the 24.2-kev transition presents some difficulty on account of the low energies of the conversion lines. Previously, analysis of the intensity of such low energy lines has not been attempted because of the difficulty of correcting for photographic sensitivity and source absorption.

The values given in Table I have been derived using large corrections for photographic sensitivity, which are consistent with Cranberg and Halpern's values,[5] and also using Richardson's analysis[6] in order to correct for source thickness. These intensity values show that the 24.2-L and 24.2-M lines represent a transition which is approximately of the same intensity as the 65.3-kev transition. Theoretically, this should be the case, since the value of the L_I shell conversion coefficient for an $M1$ transition of 24.2 kev is 7.5.[7] An indication that the corrections are of the right magnitude is shown by the L/M ratios for both transitions, which are ~4, a value which we have usually observed in previous work. The K/L ratio of the 65.3-kev transition is 0.51. This value is lower than previously obtained and is in excellent agreement with Goldhaber and Sunyar's[8] empirical curves for an $M4$ transition.

* Assisted by joint program of the ONR and AEC.
[1] J. W. Mihelich and R. D. Hill, Phys. Rev. **79**, 781 (1950).
[2] J. W. Mihelich and R. D. Hill, Phys. Rev. **77**, 743 (1950).
[3] Enriched isotope obtained from Y12 plant, Oak Ridge, Tennessee, and irradiated by special arrangement with AEC, Isotopes Division, Oak Ridge, Tennessee.
[4] Scharff-Goldhaber, der Mateosian, Goldhaber, Johnson, and McKeown, Phys. Rev. **83**, 480 (1951).
[5] L. Cranberg and J. Halpern, Rev. Sci. Instr. **20**, 641 (1949).
[6] H. O. W. Richardson, Proc. Phys. Soc. (London) **63**, 234 (1950).
[7] Gellman, Griffith, and Stanley, Phys. Rev. **80**, 1028 (1950).
[8] M. Goldhaber and A. W. Sunyar, Phys. Rev., to be published.

Three-Quantum Decay of Positronium*

MARTIN DEUTSCH
Department of Physics and Laboratory for Nuclear Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts
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THE rate of decay by three-photon annihilation of ortho-positronium—the ground state of the bound electron-positron system with spin one—has been calculated theoretically with three different results: Ore and Powell[1] find $\lambda_0=7.2\times10^6$ sec^{-1}, Lifshitz[2] gives $\lambda_0=1.13\times10^7$ sec^{-1}, Ivanenko and Sokolov[3] obtain $\lambda_0=1.6\times10^6$ sec^{-1}. Since the three papers start with the same physical assumptions, the discrepancy must be due to errors in at least two of the three calculations.

We have now determined this decay rate experimentally and find $\lambda_0=(6.8\pm0.7)\times10^6$ sec^{-1}, in excellent agreement with the value calculated by Ore and Powell and in disagreement with the other authors. This seems to be the first case in which close experimental verification of a theoretical result has been possible for a third-order radiation process.

In a previous communication[4] we have reported the abundant formation of ortho-positronium in some gases and the action of nitric oxide in low concentration to destroy it by rapid conversion to the para state. This property of NO permits us to separate effects due to ortho-positronium from other phenomena. By this means we have found that in dichlorodifluoromethane ("Freon 12") at pressures above about 0.4 atmosphere substantially all annihilation processes occurring with delays exceeding 8×10^{-8} sec are due to ortho-positronium. At lower pressures a second group appears which is not suppressed by NO and shows a rapid decay depending strongly on pressure. We make the hypothesis that this behavior is due to a large "positron attachment coefficient" of CCl_2F_2 which results in an anomalously large molecular annihilation cross section for free positrons. It may not be accidental that Freon is known to show extremely strong electron attachment.

Whatever the exact mechanism for suppressing the free posi-

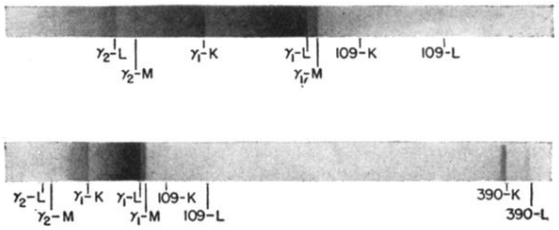

FIG. 1. Conversion spectra of Sn^{119m}. Upper spectrum, 100-gauss magnet. Lower spectrum, 200-gauss magnet. $\gamma_1 = 65.3$ kev, $\gamma_2 = 24.2$ kev; 109-kev transition from Te^{125m}, 390-kev transition from In^{113m} (produced from Sn^{124} and Sn^{112} by neutron capture and subsequent decay).