The following energies were assigned to the sample γ rays, in kev: 27.5 (Te x-rays), 60±2, 248±8, 310±10, 417±10, 463±10, 560±15?, 685±15, 772±15, 900±20, 1100±20, and 1350±20.

The γ rays of energies (in kev): 463 (100%), 772 (45%), 248 (26%), 310 (11%), and 60 (6%) have a half-life of 88±2 hours. The γ-rays of energies (in kev): 685 (100%), 417 (26%), 900 (10%), 1100 (~5%), and 1350 (~1%) have a half-life of 149±4 hours. The γ ray of 610 kev belongs to another antimony of much longer half-life.

The half-life of 88±2 hours was assigned to the Sb^{127}. The half-life of 149±4 hours belongs to another source which cannot be separated by chemical methods from Sb^{127}.

We are now trying to identify the source of the (149±4)-hour half-life. β-γ and γ-γ coincidences are being made.

ACKNOWLEDGMENTS

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Internal Bremsstrahlung and Decay Scheme of Sb^{119}†

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The spectrum and yield of internal bremsstrahlung accompanying electron capture form S and P states in Sb^{119} were measured and compared with the theory of Glauber and Martin. Sb^{119} was obtained as the daughter from Te^{119} produced by the $Sb(d,xn)Te^{119}$ and $Sn(\alpha,xn)Te^{119}$ reactions. The decay is by orbital electron capture to the 23.83-kev state in Sn^{119}. The following results were obtained: Sb^{119} half-life, 38.0 hr; $Sb^{119}-Sn^{119}$ decay energy, 579±20 kev; half-life of the 23.83-kev state and its total conversion coefficient, $(1.85\pm0.1)\times10^{-8}$ sec and 6.3±0.4, respectively. The intensity of internal bremsstrahlung for capture from S states was $(1.06\pm0.15)\times10^{-4}$ quanta/K capture. This agrees with the theoretical prediction of 0.97×10^{-4}. The large contribution at low energies from P-state capture was measured down to 70 kev and agrees with the theory in its present state of completion.

I. INTRODUCTION

THE nuclide Sb^{119} was first reported by Coleman and Pool.[1] By bombarding tin with deuterons, they found a 39-hour K x-ray activity which they assigned to Sb^{119}. Later Lindner and Perlman[2] showed a 39-hour antimony K x-ray activity to be the daughter of a 4.5-day isotope of tellurium produced by the irradiation of antimony with 200-Mev deuterons. Both groups reported no gamma radiation. Sn^{119m} has been examined by several investigators.[3–7] Their results (and those of the present work) are summarized in Fig. 1 and Table I. The decay of Sb^{119} to the 24-kev level in Sn^{119} was predicted from shell-model considerations by Goldhaber and Hill.[8]

At the start of this work the primary purpose was to investigate the internal bremsstrahlung (IB) accompanying electron capture in Sb^{119}. Morrison and Schiff,[9] and later Jauch,[10] predicted a spectrum shape of the

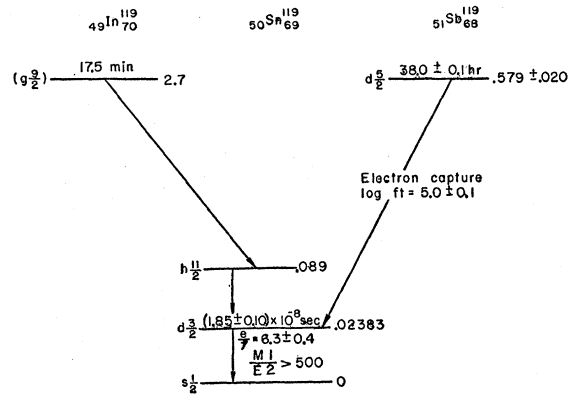

FIG. 1. Decay of Sb^{119}. Energies are given in Mev. The data associated with Sb^{119} decay are from the present work; the decay of In^{119} is taken from reference 8.

† Work performed under auspices of U. S. Atomic Energy Commission.

[1] K. D. Coleman and M. L. Pool, Phys. Rev. **72**, 1070 (1947).
[2] M. Lindner and I. Perlman, Phys. Rev. **73**, 1124 (1948).
[3] J. W. Mihelich and R. D. Hill, Phys. Rev. **79**, 781 (1950).
[4] Nelson, Ketelle, and Boyd, Oak Ridge National Laboratory Report ORNL-685, 1950 (unpublished).
[5] Scharff-Goldhaber, der Mateosian, Goldhaber, Johnson, and McKeown, Phys. Rev. **83**, 480 (1951).
[6] R. D. Hill, Phys. Rev. **83**, 865 (1951).
[7] J. G. Bowe and P. Axel, Phys. Rev. **84**, 939 (1951).
[8] M. Goldhaber and R. D. Hill, Revs. Modern Phys. **24**, 179 (1952).
[9] P. Morrison and L. I. Schiff, Phys. Rev. **58**, 24 (1940).
[10] J. M. Jauch, Oak Ridge National Laboratory Report ORNL-1102, 1951 (unpublished).

TABLE I. Internal conversion of the 23.8-kev level in Sn^{119}.

Rose calculations[a]						Experimental[b]			
	M1			$e_{LI}/e_{LII+III}$		Hill	Bowe and Axel	Present work	
e_{LI}/γ	e_{LII}/γ	e_{LIII}/γ	M2	E1	E2	e_L/γ	e_L/γ	e_T/γ	$e_{LI}/e_{LII+III}$
4.00	0.31	0.08	1.87	0.95	0.009	5.3±1.4	7.3±1.7	6.3±0.4	>4

[a] M. E. Rose, in *Beta- and Gamma-Ray Spectroscopy*, edited by K. Siegbahn (Interscience Publishers, Inc., New York, and North-Holland Publishing Company, Amsterdam, 1955), Appendix IV, p. 905.
[b] See reference 8.

form $x(1-x)^2$, where x is the quantum energy in terms of the maximum IB energy. Their treatment neglected Coulomb field effects and also assumed that capture occurs only from S states. The ratio of the total number of IB photons accompanying K capture to the total K-electron captures was given by

$$\int_0^1 \frac{N(x)dx}{N_e} = \frac{\alpha}{12\pi}\left(\frac{W_0}{m_0c^2}\right)^2, \quad (1)$$

where W_0 is the maximum IB energy. Recently Glauber and Martin[11] have treated this problem using Coulomb wave functions and have shown that capture from P states is important. Their calculations are complete only for low Z and low decay energies. They find that the shape of the spectrum associated with capture from S states agrees with that of Morrison and Schiff for low Z and should not deviate much for antimony. The yield is modified by a relativity correction factor $f(Z)$, which for antimony is 0.44.[12] For capture from P states they find that the spectra are quite weak at high energies and extremely intense near the characteristic x-ray lines. For a given energy release, the intensities of the P-state spectra increase relative to those of the S states roughly as the square of the nuclear charge. Screening corrections are important in this part of the spectrum, and for this reason a detailed comparison of the antimony P-state spectrum with theory has not been attempted in this paper.

The IB following electron capture was first observed by Bradt *et al.*[13] in Fe^{55}. Recent measurements[14–17] of IB in Fe^{55}, Ge^{71}, A^{37}, and Cs^{131} down to energies near the characteristic x-ray region have shown the existence of the large P-state contribution predicted from the Glauber-Martin theory. No quantitative information concerning intensity of the S-state spectrum has been obtained to date with sufficient accuracy to test the Z dependence predicted by Glauber and Martin.

II. SOURCE PREPARATION

A source for use in IB measurements should be free from contamination activities by a factor of at least 10^5 because of the low intensity of the IB. Our Sb^{119} was prepared by two methods. In the first, antimony metal was bombarded for several hours with 190-Mev deuterons from the Berkeley 184-inch cyclotron. In the second method, tin metal was bombarded for two hours with 48-Mev alpha particles in the Berkeley 60-inch cyclotron. In each case a tellurium fraction was chemically separated from the dissolved target and was highly purified from antimony through a series of six chemical separation cycles. Sb^{119} was then allowed to grow from the four-day Te^{119} parent. The Sb^{119} was then separated in a carrier-free state from tellurium activities through a series of six separation cycles. The resultant radiochemical purity was such that the decay over nineteen half-lives showed no deviation from a straight line when followed on a NaI(Tl) scintillation counter. A least-squares analysis of eight decay curves yielded a half-life of 38.0±0.1 hours.

III. EXPERIMENTS

A. General Information

Four types of experiments were performed: (1) gamma- and beta-ray spectrum measurements using NaI(Tl) and anthracene crystals, (2) slow coincidence experiments ($2\tau=2\times10^{-6}$ sec), (3) high-resolution measurements in a permanent magnet beta-ray spectrograph,[18] and (4) fast delayed coincidence experiments ($2\tau=6\times10^{-8}$ sec). The NaI(Tl) crystals for measurements in the x-ray region were 1 in.×1½-in. diameter right circular cylinders.[19] In the coincidence experiments lead shielding was placed between the crystals to prevent false coincidences due to scattering. A 2 in.×1¾-in. diameter NaI(Tl) crystal[19] was used for IB ($W_0=526$ kev) measurements. The NaI(Tl) crystals all gave energy resolution (full width at half-maximum of the photopeak) of 9% at 662 kev. Energy calibration points were obtained with gamma rays of 22.1, 59.7, 87.5, 138, 269, 478, and 662 kev from Cd^{109}, Am^{241}, Se^{75}, Be^7, and Cs^{137}. The anthracene crystals ranged in thickness from ½ to 1 inch, and were 1½ inches in diameter. A 256-channel pulse-height analyzer[20] utilizing the Wilkinson method of pulse height to time conversion and magnetic core storage was used to record the IB data.

[11] R. J. Glauber and P. C. Martin, Phys. Rev. **95**, 572(1954) and **104**, 158 (1956). See reference 17 for a brief summary of this theory.
[12] R. J. Glauber (private communication).
[13] H. Bradt *et al.*, Helv. Phys. Acta **19**, 222 (1946).
[14] L. Madansky and F. Rasetti, Phys. Rev. **94**, 407 (1954).
[15] B. Saraf, Phys. Rev. **94**, 642 (1954).
[16] B. Saraf, Phys. Rev. **95**, 97 (1954).
[17] T. Lindquist and C.-S. Wu, Phys. Rev. **100**, 145 (1955).
[18] W. G. Smith and J. M. Hollander, Phys. Rev. **101**, 746 (1956).
[19] Mounted in sealed aluminum containers with MgO reflectors and 10-mil Be windows.
[20] R. W. Schuman and J. P. McMahon, Rev. Sci. Instr. **27**, 675 (1956).

A 50-channel analyzer of the type developed by Ghiorso and Larsh[21] was used in the coincidence experiments. The fast-slow coincidence apparatus is similar to that described by several authors.[22] Experiments performed with Co^{60} using NaI(Tl) detectors showed that lifetimes as short as 1×10^{-9} sec could be measured.

B. Decay Scheme

In the experiments with single scintillation spectrometers, only the IB and a photopeak ascribed to the 25.2-kev tin K x-rays were observed. However, coincidence experiments showed that the x-rays were in coincidence with a gamma ray of nearly identical energy. A search was made for the IB in coincidence with the tin K x-rays, but because of source strength limitations imposed by our equipment the observed spectrum was too weak for useful analysis.

In order to determine the energy and to examine the L subshell internal conversion coefficients of the ~24-kev gamma ray, two sources of Sb^{119} of approximately 4×10^{7} and 2×10^{6} disintegrations per minute, respectively, were examined by Dr. J. M. Hollander with a permanent-magnet beta-ray spectrograph. These sources were deposited carrier-free on a 10-mil platinum wire by electrolysis of a 1.2 normal HCl solution of Sb^{119} containing hydroxylamine. Two days exposure in the spectrograph yielded measurable electron lines from the L_{I} and M shells, which gave a gamma-ray energy of 23.83 ± 0.03 kev. The $L/(M+N)$ and $L_{\mathrm{I}}/(L_{\mathrm{II}}+L_{\mathrm{III}})$ conversion ratios were estimated to be ~3 and >4, respectively.

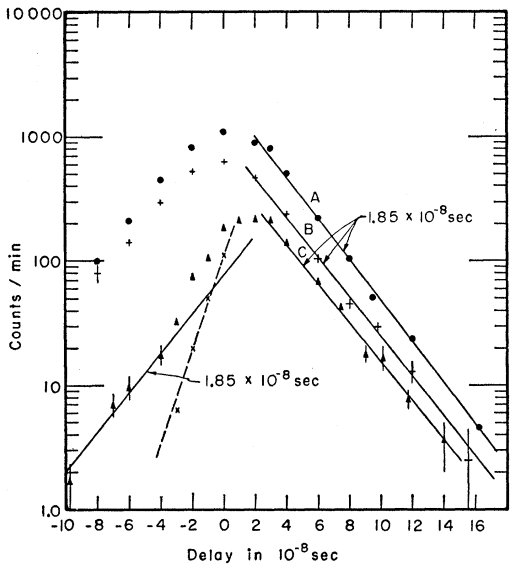

FIG. 2. Delayed coincidence measurement of the lifetime of the 23.83-kev state in Sn^{119}. Curve A: NaI(Tl) detectors. Curve B: Anthracene detectors (multiply curve by 1.3 to obtain true counting rate). Curve C: NaI(Tl) detectors with 90.8-mg/cm² Pd absorbers in front of the gamma detector. The broken line was obtained by subtracting the 1.85×10^{-8}-sec tail due to Pd fluorescent x-rays.

The measurement by delayed coincidences of the lifetime of the 23.8-kev state was complicated by the fact that the detectors could not resolve the gamma ray and the x-ray. This resulted in a symmetrical curve of coincidence rate *vs* delay, regardless of the half-life of the state (Fig. 2). Since the measured half-life of 1.85×10^{-8} sec was near the expected lower limit that could be measured with our apparatus (8×10^{-9} sec at 25 kev for NaI(Tl) detectors), two experiments were performed to prove that a lifetime really was observed. The first test consisted of replacing the NaI(Tl) crystals with anthracene. This should make it possible to measure half-lives shorter by a factor of ~5 because of the shorter decay time of the scintillator. The same half-life was observed as for NaI(Tl) detectors (Fig. 2). Incidentally, the 24-kev radiations gave prominent photopeaks in anthracene.

A second check was to discriminate strongly against x-rays in one crystal by use of a critical absorber (palladium). This gave the unsymmetrical curve shown in Fig. 2, in which the left side should have a slope determined by the speed of the apparatus. It appears to be a two-component decay curve, because some fluorescent palladium x-rays enter the crystal and have the half-life of the 23.8-kev gamma ray. A subtraction of the 1.85×10^{-8} sec tail is shown and indicates that for this energy half-lives down to ~9×10^{-9} sec can be measured with NaI(Tl) detectors in this equipment.

C. Internal Bremsstrahlung

The IB spectra were measured in a 2-in. NaI(Tl) crystal spectrometer shielded by a large lead house of 2-inch wall thickness. This house was designed to minimize backscattering by providing a minimum distance of 12 inches from the source to the lead walls. The backscatter observed using Be^{7} (478 kev) was 2.9% of the total counts at 3.6 cm source distance. Most of the backscatter is concentrated in the energy region from 50 to 200 kev. A linear relationship between percent of backscattering and gamma-ray energy was assumed[23] (Fig. 3). The total amount of backscattering was obtained by graphical integration over the observed IB spectrum and amounted to ~5% of the counts per channel at 120 kev (see Fig. 4).

It was necessary to attenuate the intense x-rays and gamma rays in order to prevent "pileup" of pulses in the electronics. Absorbers of 93.7 and 63.6 mg/cm² lead and 221 mg/cm² copper were used in the various runs. Source distances of 3.6, 4.5, and 6.5 cm from the detector were used; in the absorption corrections the effect due to oblique penetration through parts of the absorber was corrected for. Total absorption coefficients

[21] A. E. Larsh and A. Ghiorso, University of California Radiation Laboratory Report UCRL-2657, July, 1954 (unpublished).
[22] F. K. McGowan, Phys. Rev. **93**, 163 (1954).
[23] This relationship is only approximate but should be sufficient in view of the small magnitude of the correction. See G. J. Hine and R. C. McCall, Nucleonics **12**, No. 4, 27 (1954).

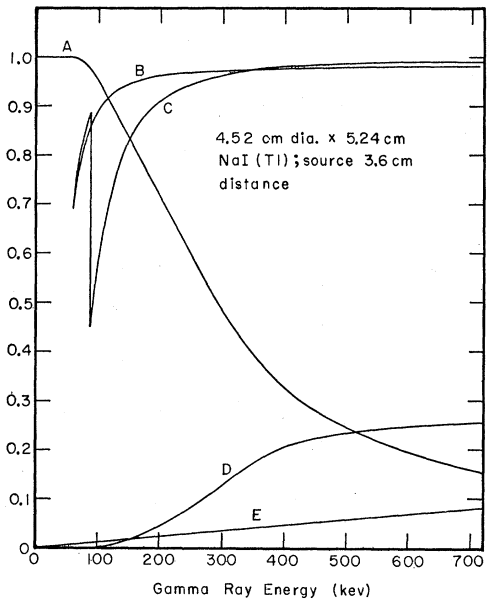

FIG. 3. Curves used for interpretation of the NaI(Tl) pulse-height spectrum. Curve A: Photopeak efficiency in NaI. Curve B: Transmission through 221 mg/cm² copper. Curve C: Transmission through 93.7 mg/cm² lead. Curve D: Compton efficiency in NaI. Curve E: Fraction of counts due to backscattering.

from Davisson's tables[24] for lead and copper were used (see Fig. 3 for the magnitude of the corrections). The use of two different absorber materials, and also of different source distances, was intended to show possible effects due to fluorescent lead x-rays and Compton-scattered photons entering the detector. Fluorescent lead x-rays contributed about 20% of the counts at 72 kev in those runs using lead absorbers. The error incurred from using total absorption coefficients for these relatively poor geometry experiments should be less than one percent at all energies of interest, because Compton scattering in these absorbers was small compared with photoelectric effect. The data were not used below 60 kev because of large absorption corrections and the danger of pileup of x-ray pulses.

In each run the rate of K-electron capture multiplied by the detector solid angle was determined by counting the K-series x-rays (and gamma rays) from a weak Sb^{119} source, without absorbers. The weak source was then compared with the source used for IB measurements by counting the radiations from both samples in a NaI(Tl) crystal with a single-channel discriminator and also in a methane-filled proportional counter. These data were used with the gamma-ray conversion coefficient (6.3) and the K-shell fluorescence yield[25] of tin (0.84) to calculate the rate of K capture in the IB sources. Small corrections were applied for dead-time in the 256-channel analyzer (up to 3%) and absorption in the Be and MgO window (7%).

The following procedure was used to determine the IB spectrum. First the pulses ascribed to backscatter were removed from the pulse-height spectrum. Then the energy-dependent corrections for NaI(Tl) crystal efficiency and resolution were made, including the effect of the Compton tail which was small but not negligible. Finally the correction for gamma rays lost in the lead or copper absorber was made.

The method of Gerhart, Carlson, and Sherr[26] was used for the crystal response corrections. In this method the relation between the pulse-height spectrum, $n(V)$, and the gamma-ray spectrum, $N(k)$, is given by

$$n(V)=\int P(V,k)N(k)dk, \qquad (2)$$

where $P(V,k)dVdk$ is the probability that a gamma ray of energy k in the interval dk will produce a pulse height V in the interval dV. A family of curves for $P(V,k)$ was obtained from experimental data on the crystal response for monoenergetic gamma rays, and Eq. (2) was then solved by trial and error for $N(k)$. This procedure was not too laborious in the present case because the pulse-height spectrum was a reasonably good approximation to the true gamma-ray spectrum.

The Compton and photoefficiencies in NaI(Tl) required for the functions $P(V,k)$ were obtained by the

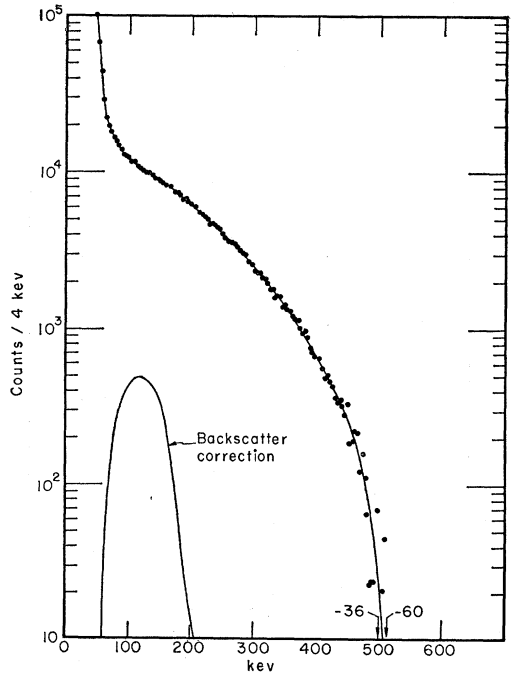

FIG. 4. Pulse-height spectrum of the IB in Sb^{119} observed with a NaI(Tl) spectrometer during a 1063-minute run. Background has been subtracted. The data were recorded in a 256-channel analyzer.

[24] C. M. Davisson, in *Beta- and Gamma-Ray Spectroscopy*, edited by K. Siegbahn (Interscience Publishers, Inc., New York, and North-Holland Publishing Company, Amsterdam, 1955), Appendix I, p. 857.

[25] Broyles, Thomas, and Haynes, Phys. Rev. **89**, 715 (1953).

[26] Gerhart, Carlson, and Sherr, Phys. Rev. **94**, 917 (1954).

method of Kalkstein and Hollander.[27] Gamma rays of 1.28, 0.840, 0.662, 0.511, 0.479, and 0.279 Mev were used to determine the ratios of photo and Compton absorption to total absorption as a function of energy. Then a curve of total efficiency *vs* energy was calculated[28] for the desired source distances, using total absorption coefficients for NaI with the coherent scattering removed.[29] From these data the efficiency curves in Fig. 3 were obtained. The functions $P(V,k)$ were then calculated by assuming Gaussian photopeaks having the experimental half-widths, and rectangular Compton distributions extending from zero pulse height to the maximum Compton recoil energy.

Five runs were made with sources ranging from 2.0×10^7 to 10.5×10^7 K-capture decays per minute. These gave x-ray counting rates through the absorbers of 0.5×10^4 to 7.0×10^4 counts per minute. The data from one run are shown in Fig. 4. All runs were weighted equally in obtaining the final results.

The close agreement among runs for which the counting rates differed by more than a factor of 10 gave confidence in the results. However, since discrepancies were encountered when these sources were run on our 50-channel analyzer, the question of whether the high counting rates in the x-ray channels could affect the energy calibration and dead-time of the 256-channel analyzer was checked in an independent experiment. Cd^{109} sources (22.1-kev x-rays, 87.5-kev γ ray) were run at counting rates up to 2×10^5 counts per minute and the peaks were used to check energy calibration and intensity ratios. Negligible changes were observed at the highest counting rates.

IV. DISCUSSION OF RESULTS

The assignment of the 38-hour antimony activity to Sb^{119} seems conclusive in view of its decay to the isomeric 23.8-kev state in Sn^{119}. Further supporting evidence exists from a comparison of the beta-decay energies observed in this work with the energy systematics of Way and Wood.[30] Evidence has been obtained for the decay energies in two Te→Sb→Sn chains. In the 4.5-day chain the energies are ~2.4 and 0.579 Mev, respectively, and in the 6.0-day chain they are <1.02 and 2.63 Mev.[31] If the 4.5-day chain is assigned mass 119 and the 6.0-day chain mass 118, a very consistent picture is obtained. The only other neutron-deficient nuclide at all likely to occur in our methods of production would have mass 117.

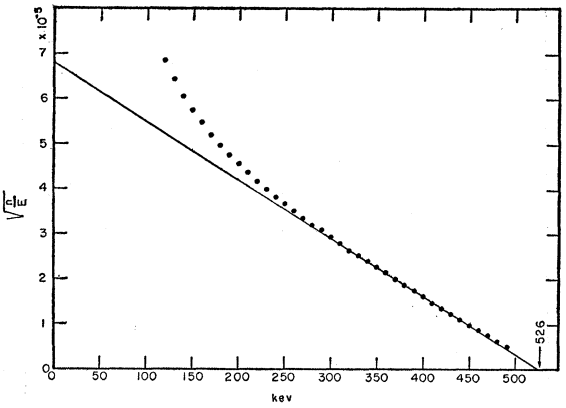

FIG. 5. Kurie-type plot of the IB spectrum in Sb^{119}. The data from 5 runs were averaged to obtain this curve. Similar plots were made for each run separately.

The logft value of 5.0[32] characterizes the electron capture decay as allowed. This is consistent with the spin and parity predictions from the shell model,[33] which also predicts that the decay should go entirely to the 23.8-kev state. With this assumption a total conversion coefficient can be calculated from our coincidence data and crystal geometries. It turns out that a comparison of these results, and those from the permanent magnet spectrograph, with theoretical L-shell conversion coefficients[34] proves that the decay goes predominantly through the 23.8-kev state.

Referring to Fig. 1, the singles and coincidence counting rates are, for detection efficiencies of 100%,

$$n_1=\Omega_1 N\left(\frac{K}{K+L}w_K+\frac{\gamma}{\gamma+e}\right), \tag{3}$$

$$n_2=\Omega_2 N\left(\frac{K}{K+L}w_K+\frac{\gamma}{\gamma+e}\right), \tag{4}$$

$$n_{1,2}=2\Omega_1\Omega_2 N\left(\frac{K}{K+L}w_K\right)\left(\frac{\gamma}{\gamma+e}\right), \tag{5}$$

where N is source strength, Ω is crystal geometry, w_K is K-shell fluorescence yield, and K, L, γ, and e are the number of K-electron captures, L-electron captures, gamma rays, and conversion electrons, respectively. When one uses the value $L/K=0.135$,[35] these equations give the total conversion coefficient $e/\gamma\leq6.3\pm0.4$. The equal sign applies if our assumption of 100% decay through the 23.8-kev state is correct. When this result is compared with the theoretical values (see

[27] M. I. Kalkstein and J. M. Hollander, University of California Radiation Laboratory Report UCRL-2764 (1954), (unpublished).
[28] Bell, Davis, Hughes, Jordan, and Randall, Oak Ridge National Laboratory Physics Department Quarterly Report ORNL-1415, 1952 (unpublished); B. Kahn and W. S. Lyon, Nucleonics **11**, No. 11, 61 (1953).
[29] G. R. White, National Bureau of Standards Report NBS-1003, 1952 (unpublished).
[30] K. Way and M. Wood, Phys. Rev. **94**, 119 (1954).
[31] Lindner, Mann, Olsen, and Howland (unpublished work).
[32] S. A. Moskowski, Phys. Rev. **82**, 35 (1951).
[33] M. G. Mayer, Phys. Rev. **78**, 16 (1950); Haxel, Jensen, and Suess, Phys. Rev. **75**, 1766 (1949).
[34] M. E. Rose, in *Beta- and Gamma-Ray Spectroscopy*, edited by K. Siegbahn (Interscience Publishers, Inc., New York, and North-Holland Publishing Company, Amsterdam, 1955), Appendix IV, p. 905.
[35] H. Brysk and M. E. Rose, ORNL-1830 (1955).

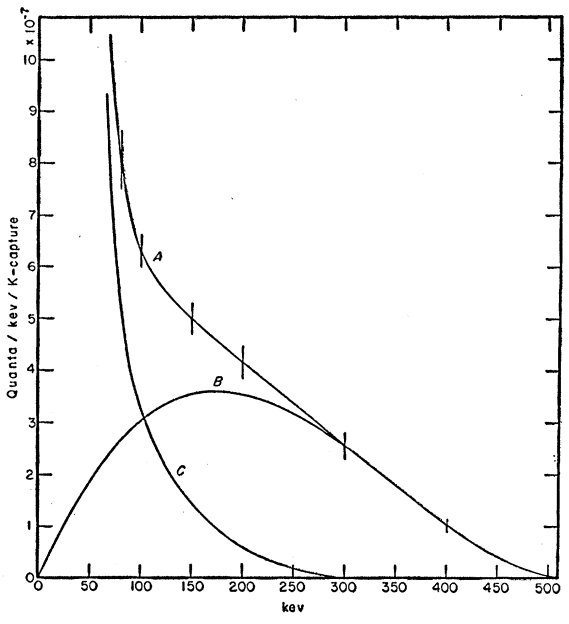

FIG. 6. The IB spectrum in Sb^{119}. Curve A: Total spectrum. Curve B: Spectrum accompanying capture from S-states, constructed from the linear extrapolation in Fig. 5. Curve C: Spectrum accompanying capture from P-states. See text for comment on the validity of this breakdown of curve A.

Table I), it is seen that the radiation must be predominantly $M1$ or $E1$. But $E1$ is ruled out by the beta spectrograph data. If the theoretical value of 4.4 for $M1$ conversion in the L shell is assumed to apply in this case, then the $M+N$ conversion coefficient is 1.9 ± 0.4. This is in satisfactory agreement with the rough estimate of 1.5 that was made by visual observation of the spectrograph film.

From the ratio of L subshell conversion intensities, a lower limit of 500 can be placed on the $M1/E2$ mixing ratio. This places a lower limit of 8×10^{-5} sec on the $E2$ radiative mean life, a factor of $\sim$20 lower than the single-particle estimates.[36] The $M1$ radiative mean life of $(19.5\pm1.0)\times10^{-8}$ sec is $\sim$70 times longer than the single particle estimates.

Each set of data on the IB spectrum was corrected from 50 to 500 kev for backscatter, crystal response, and absorption, and was plotted in linear form (Fig. 5) according to the method of Jauch.[10] The end-point energy of the $1S$ spectrum was found to be 526 ± 20 kev. The S-capture component was extended to zero energy and converted back to the spectrum of the form $x(1-x)^2$. This spectrum was then subtracted from the total to give the spectrum resulting from P capture (Fig. 6). The ratio of the total number of IB photons from S-capture to the total K-electron capture was found to be $(1.06\pm0.15)\times10^{-4}$. This is in satisfactory agreement with the predicted yield of 0.97×10^{-4} from Eq. (1) modified by Glauber and Martin's theory. The energy (102 kev) at which the P- and S-spectra have equal intensities is in good agreement with the theoretical prediction. The total spread among the five runs was 7% in yield and 5% in end-point energy. The principal factor affecting the magnitudes of the error bars in Fig. 6 was the crystal response correction for energies above 200 kev and the absorber correction for energies below 100 kev.

The correctness of this method for separating the P and S components in the IB spectrum depends entirely on the assumption that the S spectrum has the form $x(1-x)^2$. This is expected to hold for antimony with sufficient accuracy to give a meaningful comparison between our results and the Glauber-Martin theory. More detailed results from the Glauber-Martin theory applied to antimony are expected to appear in a later paper by these authors.[12]

V. ACKNOWLEDGMENTS

The authors wish to thank Professor R. J. Glauber for several discussions about the IB and for sending us results from his and P. C. Martin's theoretical calculations prior to publication. We also thank Dr. J. M. Hollander for performing the experiments in his spectrometer and Miss Frances Latell for assistance in taking some of the data.

[36] M. Goldhaber and A. W. Sunyar, in *Beta- and Gamma-Ray Spectroscopy*, edited by K. Siegbahn (Interscience Publishers, Inc., New York, and North-Holland Publishing Company, Amsterdam, 1955), Chap. XVI (part II), p. 453.