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$E2/M1$ Ratios in the Isomeric Transitions of Te^{121} and Te^{123}, and the Decay of the Te^{121} Isomers to Sb^{121}†

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The decay of Te^{121} isomers and the decay of Te^{123m} have been investigated with scintillation and proportional counter spectrometers, coincidence techniques, and a high resolution beta-ray spectrometer for the measurement of the conversion spectrum. In the decay of the Te^{121} isomers to levels of Sb^{121}, transitions of the following energies have been found: 37, 66, 470, 508, 573, and 1110 keV. The 37, 1110, and 66 508 cascades have been established by coincidence measurements. A 37, 470 cascade is indicated by precision energy measurements. Coincidences between the 66- and 1110-keV transitions expected to occur on the basis of reports in the literature, could not be found. By a careful analysis of the conversion spectrum, it was possible to determine, from L subshell ratios, the multipolarities of most of the gamma rays. A decay scheme is proposed which accounts for all of the observed data and in which the first-excited state in Sb^{121} lies at 37 keV. The half-life of the 37-keV level in Sb^{121}, measured by the delayed coincidence method, was found to be $(3.5\pm0.2)\times10^{-9}$ sec. Furthermore, from the analysis of the $L_1/L_2/L_3$ ratios observed in the conversion spectrum, the $E2/M1$ ratio values could be determined for the 212- and 159-keV transitions in Te^{121m} and Te^{123m}, respectively. The results are: $E2/M1=0.050$ for the 212-keV transition and $E2/M1=0.0067$ for the 159-keV transition. The $E2$ speeds of these transitions have been inferred from the known lifetimes of the 212-keV state in Te^{121} and of the 159-keV state in Te^{123}; the results are 26 and 4.5 times the single-particle speeds, respectively.

I. INTRODUCTION

THE decay of Te^{121} isomers and the decay of Te^{123m} have been studied by a number of investigators.[1,2] As a result of their work, some decay characteristics of these nuclei have been determined. In particular, it has been established that Te^{121m} and Te^{123m} decay to the ground states via $M4$ transitions followed by $M1+E2$ transitions, the latter interpreted as occurring between $d_{3/2}$ and $s_{1/2}$ single-particle states. However, several uncertainties have still existed concerning especially the position of the 66-keV transition[3] in the Sb^{121} level scheme and the $E2/M1$ admixture[4] values for the 212-keV transition in Te^{121m} and the 159-keV transition in Te^{123m}.

There is general agreement on the presence of a 508, 66-keV γ-γ cascade in the 17-day Te^{121} decay, but not on the sequence of these two gamma rays. Based on the systematic trend[5] of the $g_{7/2}$ level in neighboring nuclei, several authors[6,7] have suggested the existence of a level at 66 keV. However, the level sequence thus resulting is questionable because the intensity of the 66-keV transition seems to be considerably smaller than the intensity of the 508-keV transition populating the 66-keV level. One way to avoid this difficulty would be to consider levels in Sb^{121} at 508- and 573-keV, with the 66-keV transition occurring between them. This

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[1] *Nuclear Data Sheets*, compiled by K. Way *et al.* (Printing and Publishing Office, National Academy of Science—National Research Council, Washington, D. C.), NRC 60-4-80 and 81.
[2] *Nuclear Data Sheets*, compiled by K. Way *et al.* (Printing and Publishing Office, National Academy of Science— National Research Council, Washington, D. C.), NRC 60-6-69 and 70.
[3] This is the transition which has been generally designated as the 70-keV transition. Energies used hereafter in this paper are those measured in the work here reported.
[4] M. Schmorak, A. C. Li, and A. Schwarzschild, Phys. Rev. **130**, 727 (1963).
[5] A. H. Wapstra, Physica **19**, 671 (1953).
[6] R. K. Gupta, S. Jha, and B. K. Madan, Nuovo Cimento **9**, 1117 (1958).
[7] R. K. Gupta, Nuovo Cimento **17**, 665 (1960).

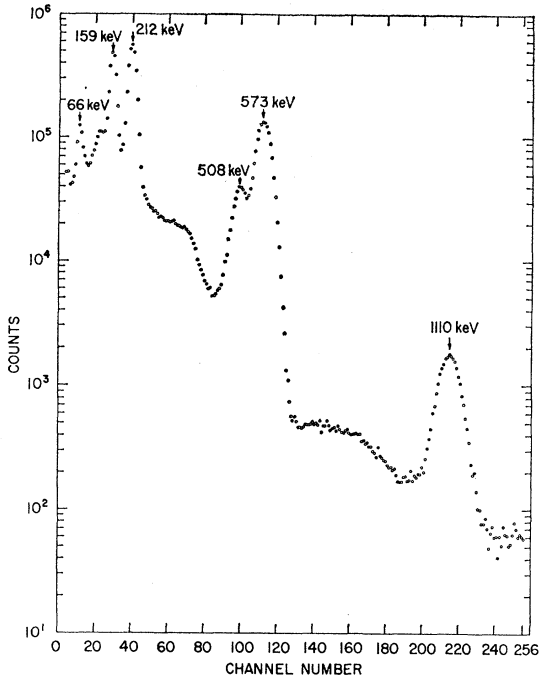

FIG. 1. Gamma-ray spectrum of Te^{121}, Te^{121m}, and Te^{123m} mixture.

level order has been proposed by some investigators.[8,9] It would leave unexplained, however, the absence of a low-lying state in Sb^{121}, expected from the systematic trend of the $g_{7/2}$ and $d_{5/2}$ levels in the odd-A antimony isotopes, and the reported observation of 1110–66-keV coincidences in the electron-capture decay of 154-day Te^{121m}.[7,10]

The $E2/M1$ ratios for the 212-keV and 159-keV transitions in Te^{121m} and Te^{123m} have been determined by angular correlation measurements.[11] In the case of Te^{123m} the $E2$ lifetime derived from Coulomb excitation[12] does not agree with that derived from the angular correlation result and the over-all lifetime.[4] In the present work, the decay of Te^{121} isomers and the decay of Te^{123m} have been reinvestigated in an attempt to resolve these several discrepancies and questions.

II. SOURCE PREPARATION

The sources used in this work were prepared from an essentially carrier-free solution of high activity. A thick target of natural metallic antimony was irradiated in the Brookhaven 60-in. cyclotron with about 500 μA hours of 20-MeV deuterons. Te^{121}, Te^{121m}, and Te^{123m} were produced by $(d,2n)$ reactions on Sb^{121} and Sb^{123}. After the short-lived activities had decayed, the antimony was dissolved in aqua regia. The tellurium activity was coprecipitated with selenium carrier from $3N$ hydrochloric acid solution by reduction with sulfur dioxide gas. After it was separated from the solution and washed, the precipitate was dissolved in a few drops of concentrated nitric acid; the selenium carrier was then driven off by boiling with concentrated hydrobromic acid, leaving the tellurium activity behind in the solution. This coprecipitation cycle was repeated several times in order to remove more completely unwanted activities. Finally, the tellurium was electroplated onto a masked-off area, $\frac{3}{4}$ mm by 15 mm, on a rotating gold cathode. A platinum wire in a separate compartment was the anode.[13] The electrolysis was carried on with a current of 0.2 mA for several hours to achieve a yield of about 25%.

III. MEASUREMENTS WITH SCINTILLATION AND PROPORTIONAL COUNTERS

A. Gamma-Ray Spectrum

The gamma-ray spectrum was measured with a 3 in.×3 in. NaI(Tl) scintillation counter and a multichannel analyzer. The "singles" spectrum is reproduced in Fig. 1. Along with the 212-keV gamma ray from Te^{121m} and the 159-keV gamma ray from Te^{123m}, there are the well-known 508- and 573-keV gamma rays from Te^{121} and the 1110-keV transition from Te^{121m}; the highly converted 88- and 82-keV $M4$ transitions from the two isomers do not appear. The relative intensities of the γ rays as determined from this singles spectrum with corrections for the appropriate efficiency factors,[14] are presented in Table I. The intensity of the 66-keV gamma ray was determined from coincidence measurements described below. The 66-keV line present in the singles spectrum is predominantly due to the Au x rays from the source backing. Analysis of the 508-keV, 573-keV complex photopeak was done with the aid of photopeaks observed with standard sources.

TABLE I. Gamma-ray intensities for Te^{121} and Te^{121m} as determined from the scintillation spectrometer measurements.

E_γ (keV)	Parent state	Relative intensity
66	Te^{121}	0.4±0.1
508	Te^{121}	24±4
573	Te^{121}	100
212	Te^{121m}	100
1110	Te^{121m}	3.3±0.5

[8] R. D. Hill, P. Axel, and A. W. Sunyar (private communication) quoted by J. M. Hollander, I. Perlman, and G. T. Seaborg, Rev. Mod. Phys. **25**, 469 (1958).

[9] K. S. Bhatku, R. K. Gupta, S. Jha, and B. K. Madan, Nuovo Cimento **6**, 1461 (1957).

[10] R. Bhattacharya and S. Shastry, Nuclear Phys. **41**, 184 (1963).

[11] N. Goldberg and S. Frankel, Phys. Rev. **100**, 1350 (1955).

[12] L. W. Fagg, E. A. Wolicki, R. O. Bondelid, K. L. Dunning, and S. Snyder, Phys. Rev. **100**, 1299 (1955).

[13] A. S. Ghosh Mazumdar, Proc. Indian Acad. Sci. **A48**, 106 (1958).

[14] R. L. Heath, Gamma-Ray Spectrum Catalogue, Phillips Petroleum Company, IDO-16408 (unpublished).

B. Coincidence Studies

Gamma-gamma coincidence measurements were performed with a pair of 3 in.×3 in. NaI(Tl) crystals. The two detectors were placed to subtend a 45° angle at the source, and a lead absorber $1\frac{1}{2}$ in. in thickness was interposed between them in order to prevent interference from scattering effects. The 1110-, 573-, and 508-keV γ-rays were each chosen to gate a coincident scintillation spectrum, which was displayed on a multichannel analyzer. The following conclusion could be drawn from these measurements. The 1110-keV transition is not in coincidence with the 66-keV transition, as has been reported,[7,10] but appears to be in coincidence with an ≈40-keV transition. No other radiations except for x rays are in coincidence with the 1110-keV transition.[15,16] Further, the 508-keV and 66-keV γ rays are in coincidence with each other; the 573-keV γ ray is not in coincidence with any other γ ray. All these radiations were, of course, found to be in coincidence with K x rays. The intensity of the 66-keV gamma ray relative to that of the 508-keV gamma was determined from the 508-, 66-keV γ,γ coincidence rate relative to the 508-keV gamma singles rate.

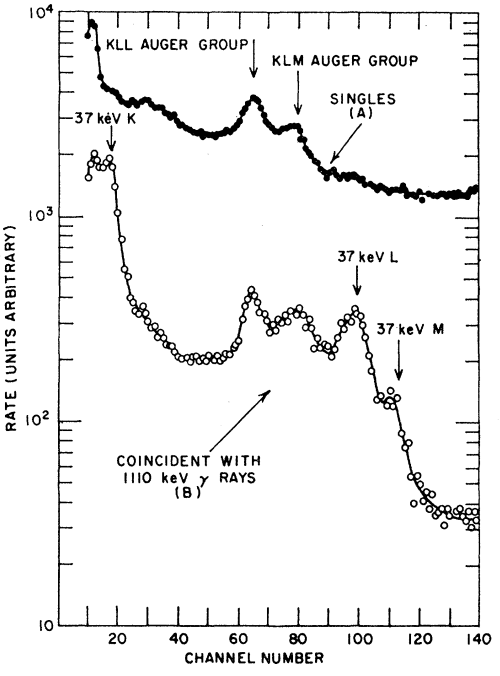

FIG. 2. Conversion-electron spectra of Te^{121} isomers measured with a proportional counter.

[15] If indeed the 1110-keV transition were in coincidence with the 66-keV radiations, and if the latter transition is of $M1$ multipole order, both as reported by Gupta (Ref. 7), then the relative rates of x rays and 66-keV radiations should have been different from that he observed, shown in Fig. 1, Ref. 7.

[16] Analysis of the overlapping x-ray and ≈40-keV gamma-ray peaks observed in this work to be in coincidence with the 1110-keV gamma ray shows that only a small fraction of the radiations with energy about 1100 keV, not over 20%, could be produced by ground-state transitions.

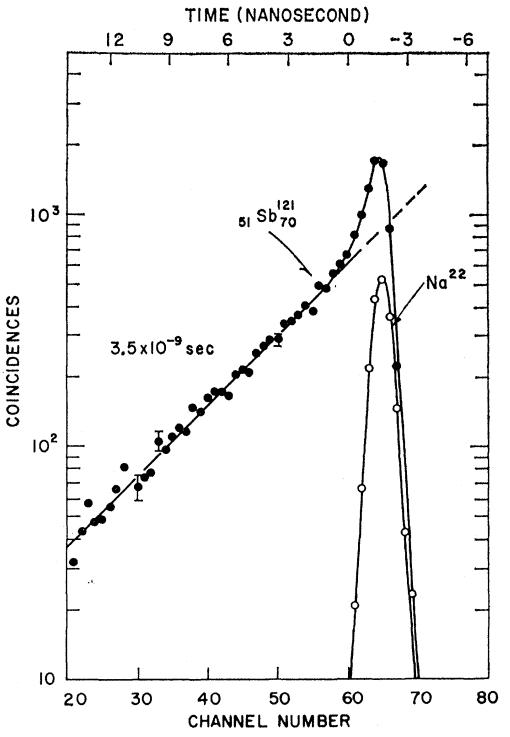

FIG. 3. Delayed coincidence time spectrum for the 37-keV transition in Te^{121}–Sb^{121}.

The cascade relationships were analyzed also by electron-gamma coincidence measurements, carried out with a 3 in.×3 in. NaI crystal and a gas-flow proportional counter. The counter had an aluminum body with an inside diameter of 2 in. and a length of 7 in. The center wire was 0.002-in.-diam tungsten. A 1-in.-diam, 0.010-in.-thick beryllium window was sealed into the side wall of the counter by means of "O" rings and was easily removable for insertion of the source. In practice the source was glued to the inner surface of the window, which made up part of the cathode. A commercially available mixture of 90% argon and 10% methane gas was flowed through the counter at an absolute pressure of 128 cm of mercury. Coincidences were measured between energy selected pulses from the scintillation counter and the electrons detected by the proportional counter in a range of energy from ≈3 keV to 50 keV. The electron spectrum in coincidence with the 1110-keV gamma transition is shown in Fig. 2 (Curve B); a "singles" electron spectrum (Curve A) is also shown for comparison. Curve B clearly shows the coincidence of the 1110-keV transition with three groups of electrons which correspond to the K, L, and M lines of a 37-keV transition. In addition, a small fraction of the 508-keV γ-ray intensity was found to be in coincidence with electrons of energy corresponding to K-shell conversion of the 66-keV transition. Only Auger electrons were found in coincidence with the 573-keV transition.

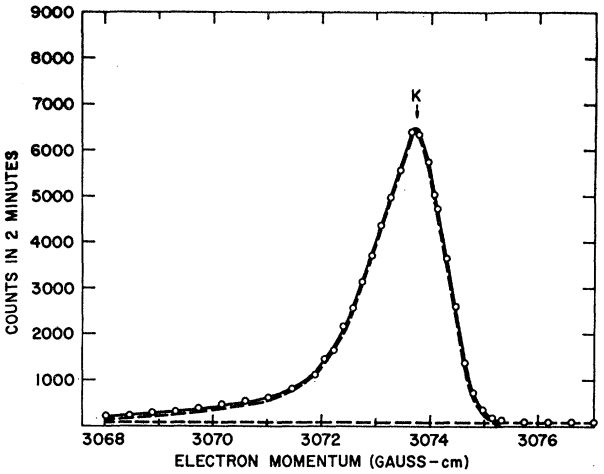

FIG. 4. K-shell conversion line of 573-keV $E2$ transition in Te^{121} observed in double focusing spectrometer.

IV. DELAYED COINCIDENCE MEASUREMENTS ON THE 37-keV, 1110-keV CASCADE

The time distribution of the delayed coincidences between the 1110-keV γ rays and the conversion electrons of the 37-keV transition was measured with a transistorized time-to-pulse-height-converter and fast discriminator which have been described in detail elsewhere.[17] The γ-ray detector was Naton-136 plastic scintillator, 2.5 cm thick by 5 cm diameter. The electron detector was made of the same material, 1 mm thick$\times$7 mm diam. Type 56 AVP photomultiplier tubes were used. The observed time spectrum is given in Fig. 3. A curve for prompt events was obtained by measuring coincidences between the β rays and the 1.17- or 1.33-MeV γ rays of Co^{60} with the same channel settings as those used for the Te measurement. The result of these measurements show that the 37-keV transition follows the 1110-keV transition, and that the half-life of the intermediate level is 3.5 ± 0.2 nsec. The large prompt contribution in the spectrum of Fig. 3, due to coincidences of the 1110-keV γ ray with x rays from electron capture, shows that the lifetime of the 1147-keV level is less than 1 nsec.

V. INTERNAL CONVERSION-ELECTRON MEASUREMENTS

A. The Spectrometer

The β-ray spectrometer used in this work, an iron, 50-cm radius, $\pi\sqrt{2}$, double focusing instrument, has been previously described.[18] A gas-flow proportional counter, maintained at a pressure of 25 mm of mercury with butene-2, served as the detector. The counter window, of total thickness 580 μg/cm^2, was made of Mylar, lightly coated with gold. Absorption corrections, necessary for electrons of energy less than 60 keV, were taken from the literature.[19] For most of the measurements the counter-slit width was 0.67 mm and the transmission solid angle was set at about 0.2% of 4π. For lines of high momentum the resolution obtained was 0.05% full-width at half-maximum intensity. The momentum scale calibration was based on measurements of conversion lines of the 155.032 ± 0.012-keV transition[20] in Os^{188}.

B. Conversion-Electron Spectra

The energy range covered in these measurements was from about 30 keV to 1200 keV, and the internal conversion lines observed originated in the decay of 154-day Te^{121m} and of the 17-day Te^{121} ground state as well as in the decay of the 104-day Te^{123m}.[1,2] From the observed energies and intensities of these lines together with the values for electron binding energies[21] in Te and Sb, and the theoretical internal conversion coefficients,[22] it was possible to deduce the multipole order and intensity of the transitions in these nuclides. The results are given in Table II.

For the 66- and 508-keV transitions, absolute values of the K-shell internal conversion coefficients may be determined from the relative γ-ray intensities and the relative conversion line intensities if one assumes the

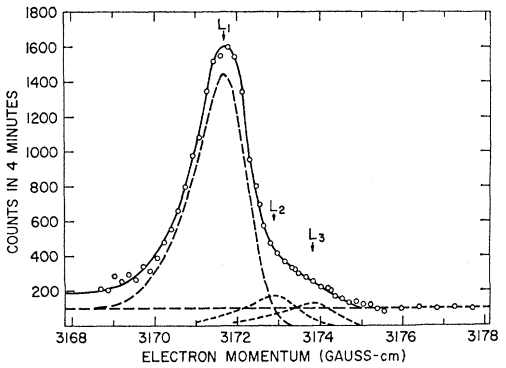

FIG. 5. L-subshell multiplet of 573-keV $E2$ transition in Te^{121} observed in double focusing spectrometer.

[17] A. Schwarzschild, in *Electromagnetic Lifetimes and Properties of Nuclear States* (National Academy of Sciences—National Research Council, Washington, D. C.), Publication No. 974, 1962. Also Nucl. Instr. Methods (to be published); Brookhaven National Laboratory Report BNL 711 (T-248), 1962 (unpublished).

[18] G. T. Emery, W. R. Kane, M. McKeown, M. L. Perlman, and G. Scharff-Goldhaber, Phys. Rev. **129**, 2597 (1963).

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[20] B. Lindström and I. Marklund, Arkiv Fysik **22**, 422 (1962); R. L. Graham, J. S. Geiger, R. A. Naumann, and J. M. Prospero, Can. J. Phys. **40**, 296 (1962).

[21] Atomic electron binding energies have been taken from the data of Y. Cauchois, quoted in *Nuclear Spectroscopy Table*, edited by A. H. Wapstra, G. J. Nijgh, and R. van Lieshout (North-Holland Publishing Company, Amsterdam, 1959).

[22] L. A. Sliv and I. M. Band, *Coefficients of Internal Conversion of Gamma Radiation* (USSR Academy of Sciences, Moscow-Leningrad, 1956 and 1958); also issued as Reports 57 ICC K1 and 58 ICC L1, University of Illinois, Urbana, Illinois (unpublished).

TABLE II. Transitions observed in the decay of Te^{121} and Te^{121m}. Results of conversion-electron measurements made with $\pi\sqrt{2}$ spectrometer.

Transition energy[a] (keV)	Conversion lines observed; basis for multipole assignment	Multipole order	Conversion line intensity[b]	Transition intensity[c]	Designation[d]
81.78±0.02	$K,L_1,L_2,L_3,M_1,M_{2,3},M_{4,5},N$. $L_1/L_2/L_3=1.00/0.22/1.67$	$M4$	34.3	90.2 ±0.5	AB Te^{121m}
212.21±0.03	K,L_1,L_2,L_3,M. $L_1/L_2/L_3=1.00/0.081/0.037$	95% $M1$ 5% $E2$	6.20	90.2 ±0.5	BC Te^{121m}
37.15±0.02	L_1,L_2,L_3. $L_1/L_2/L_3=1.00/0.075/0.026$ $(E2/M1<5\times10^{-4})$	$M1$	1.12(L_1)	11.4 ±0.5	GH Te^{121} and Te^{121m}
65.58±0.02	K,L. $K/L\leqslant6$; L line shape indicates subshell ratio ≈ ratio for $M1$ $(E2/M1<0.02)$	$M1$	0.33	0.57±0.04	EF Te^{121}
470.39±0.05	K, weak. Assignment from level scheme	$E2$	0.012	1.6 ±0.2	FG Te^{121}
507.54±0.05	K,L. L line shape indicates subshell ratio ≈ ratio for $M1$ $(E2/M1<0.1)$	$M1$	0.130	17.8 ±1.0	FH Te^{121}
573.08±0.05	K,L_1,L_2,L_3. $L_1/L_2/L_3=1.00/0.12/0.09$	$E2$	0.37	80.6 ±2.5	EH Te^{121}

[a] These energies have been determined from the leading edge of the conversion lines.
[b] Intensities given are for the K conversion lines, except where otherwise indicated. These intensities have been normalized separately for Te^{121} and Te^{121m} as described in footnote c.
[c] Transition intensities have been normalized separately for Te^{121m} and Te^{121} so that the disintegration rate of each is 100 units. The observed relative conversion line intensities were only slightly different from those tabulated because, at the time of the final intensity measurements, nearly all of the Te^{121} present had been produced by isomeric transition from Te^{121m}. Appropriate small corrections were made for growth and decay in order to obtain accurately the intensity of the 37.15-keV transition, which is produced in the decay of both isomers.
[d] The letter designations refer to the levels as labeled in Fig. 8.

theoretical value for the conversion coefficient of the well characterized 573-keV $E2$ transition. (The observed conversion lines of K-shell and L-subshell from the 573-keV transition are shown in Figs. 4 and 5.) These values are consistent with the $M1$ multipole order assignments given in Table II.

The observed L-subshell conversion lines from the 159-keV transition in Te^{123m} and from the 212.2-keV transition in Te^{121m} are shown in Fig. 6 and Fig. 7. For resolution of these multiplets into their individual components, nearby K conversion lines were taken for the standard line shape. Source thickness effects were thus made negligible. The unfolding procedure was begun at the high momentum side of the composite line, and an approximate least-squares procedure was used to adjust the height and position of the standard shape to the higher momentum part of the composite, which was produced nearly entirely by conversion in the L_3 ubshell. This procedure was repeated in order to resolved the L_2 and L_1 components from the remainder.

The $E2/M1$ gamma-ray ratios δ^2 were calculated from the measured L_1/L_2 and L_1/L_3 conversion ratios and the relation

$$\left(\frac{I_{L_1}}{I_{L_i}}\right)_{\text{obs}}=\frac{\alpha_{L_1}(M1)+\delta^2\alpha_{L_1}(E2)}{\alpha_{L_i}(M1)+\delta^2\alpha_{L_i}(E2)}, \quad (1)$$

where $\alpha_{L_i}(M1)$ and $\alpha_{L_i}(E2)$ are the theoretical L_i internal conversion coefficients for $M1$ and $E2$ transitions, respectively.[22] The results are given in Table III. The uncertainties include contributions from the standard deviation of the unfolding and from the counting statistics. Also given in Table III are the experimentally obtained and the theoretical values of the total K and L_1 internal conversion coefficients for the mixed transitions. Measured values were derived from comparison

TABLE III. $E2/M1$ ratios and K and L_1 internal conversion coefficients for the $d_{3/2}\rightarrow s_{1/2}$ transitions in Te^{121m} and Te^{123m}.

Nuclide	Transition energy (keV)	Run No.	Observed L-subshell line intensities L_1	L_2	L_3	δ^2 from $(L_1/L_2)_{\text{obs}}$[a,b]	δ^2 from $(L_1/L_3)_{\text{obs}}$	δ^2 weighted average[c]	α_K[d] obs.	α_K theor.	α_{L1} obs.	α_{L1} theor.
Te^{121m}	212.21 ±0.02	1	2366±21	194±4	86±2	0.053 ±0.006	0.049 ±0.003					
		2	1979±15	159±5	73±2	0.049 ±0.007	0.049 ±0.003	0.050 ±0.003	7.55(−2) ±0.30	7.46(−2)	9.67(−3) ±0.50	8.73(−3)
Te^{123m}	159.00 ±0.03	1	3709±26	267±9	75±5	0.0112±0.0054	0.0054±0.0014					
		2	3085±27	206±4	55±4	0.0045±0.0029	0.0024±0.0015					
		3	2825±17	199±3	56±3	0.0095±0.0028	0.0050±0.0012	0.0067±0.0011	1.69(−1) ±0.06	1.63(−1)	2.01(−2) ±0.10	1.93(−2)

[a] See Eq. (1).
[b] Internal conversion coefficients required were taken from Ref. 22.
[c] Weights are assigned in inverse proportion to the fractional uncertainty of each measurement.
[d] The α values are total conversion coefficients for the shell designated, and a value 7.55(−2) is to be read 7.55×10^{-2}.

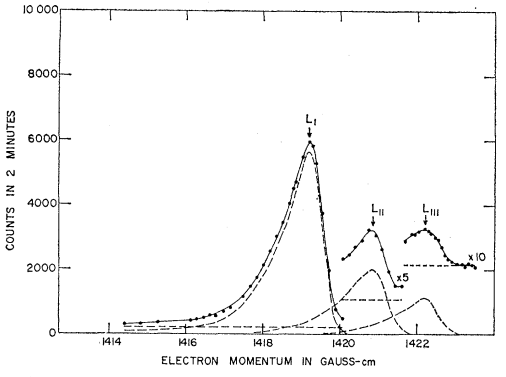

FIG. 6. L-subshell multiplet of 159-keV $E2$, $M1$ transition in Te^{123m} observed in double focusing spectrometer.

TABLE IV. Properties of the ground-state transitions in odd mass antimony isotopes.

Isotope	Transition	$E(g_{7/2})-E(d_{5/2})$ keV	$\tau_{1/2}$ meas (10^{-9} sec)	τ_γ exp/$\tau_{s.p.}$[e] $M1$ retardation
Sb^{119}	$g_{7/2} \rightarrow d_{5/2}$	270[a]		
Sb^{121}	$g_{7/2} \rightarrow d_{5/2}$	37[b]	3.5 $\pm$0.2[b]	95
Sb^{123}	$d_{5/2} \rightarrow g_{7/2}$	-160[c]	0.64 $\pm$0.05[d]	140
Sb^{125}	$d_{5/2} \rightarrow g_{7/2}$	-326[c]		

[a] R. K. Gupta, G. C. Pramila, and R. Srinivasa, Nucl. Phys. **32**, 669 (1962); R. W. Fink, G. Andersson, and G. Kantele, Arkiv. Fysik **19**, 323 (1961); G. Kantele and R. W. Fink, Nucl. Phys. (to be published).
[b] This work.
[c] *Nuclear Data Sheets*, compiled by K. Way *et al.* (Printing and Publishing Office, National Academy of Sciences—National Research Council, Washington 25, D.C.). Sb^{123}: NRC 60-6-66 through 60-6-68; Sb^{125}: NRC 60-6-94 through 60-6-97.
[d] M. Schmorak, A. C. Li, and A. Schwarzschild, Phys. Rev. **130**, 727 (1963).
[e] In the single-particle Weisskopf estimates, the statistical factors have been taken to be unity, and r_0 is taken to be 1.20 F.

of the K and L_1 line intensities for the 212- and 159-keV transitions with the line intensities of the preceding 82- and 88-keV $M4$ transitions, which are essentially completely converted. Within the uncertainties, the observed values agree with those calculated on the basis of $M1$-$E2$ mixing; there is thus no evidence for appreciable structure dependent contributions to the conversion in these predominantly $M1$ transitions.[23]

VI. DISCUSSION

The decay scheme shown in Fig. 8 results from the synthesis of the data presented in the foregoing sections. Placement of levels G and D at 37.2 and 1147 keV is required by the delayed coincidence results; and the sum-crossover relation 470.39, 37.15–507.54 keV establishes the position of level F. Coincidence results, the sum-crossover relation 507.54, 65.58–573.08 keV, and the observed transition intensities all support the location of the 66-keV transition as shown and thus the placement of level E.[24] It is evident from results in the literature[1] that the levels E and F are populated by decay from the Te^{121} ground state and that level D is populated by decay from Te^{121m}. Except for the direct population of level G by electron capture the $\log ft$ values of Fig. 8 are calculated from the assumed ground-state energy difference[1] 1.3 MeV and the intensity data of Table II. Even parity is required for levels E, F, and G by the multipole orders of the several transitions connecting these states and the measured spin $\frac{5}{2}$ ground state, presumably a $d_{5/2}$ state.[25] For level E only spin values $\frac{1}{2}$ or $\frac{3}{2}$ are consistent with the associated $\log ft$ value; and the combination of spin $\frac{1}{2}$ for this level and spin $\frac{7}{2}$ for G would account for the $M1$ order of the 37-keV transition and the absence of a transition EG. The spin value $\frac{3}{2}$ for level E cannot be excluded, however. Level G is then the expected low-lying $g_{7/2}$ state; the $g_{7/2}$–$d_{5/2}$ difference fits into the smoothly varying pattern of these differences shown by the odd mass antimony isotopes (Table IV). For level F only the spin value $\frac{3}{2}$ is consistent with the $\log ft$ value and the $M1$ multipole order of the transition FH. Transition FG is thus inferred to be of $E2$ order. It may be pointed out that the intensity of this transition, calculated from the conversion line intensity, would be essentially unchanged if the multipole order should be $M1$. For level D, the $\log ft$ value would indicate even parity; spin values of $\frac{7}{2}$, $\frac{9}{2}$, or 11/2 would be consistent with the electron-capture probability and with the observation made in this work on the lifetime of this level.

The existence of the electron-capture transition from Te^{121m} to level G is inferred from the fact that all the intensity of the transition GH is not accounted for by FG and DG. The capture transition AG is a first-forbidden "unique" decay and its $\log ft$ value, 9.0, is in the range of values expected for its classification. It is quite improbable that a β^+ spectrum with end-point energy $\sim$250 keV and abundance $\sim$4% could be produced in the decay of Te^{121}, as has been reported.[10] At this energy the capture-positron ratio should be

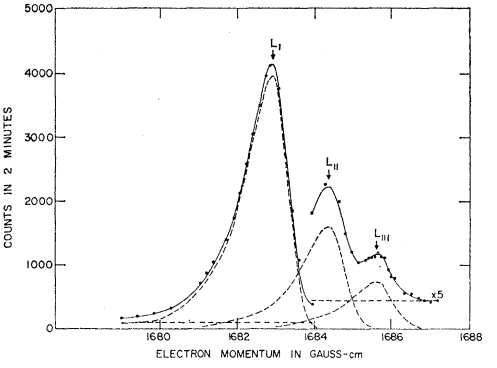

FIG. 7. L-subshell multiplet of 212-keV $E2$, $M1$ transition in Te^{121m} observed in double focusing spectrometer.

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[24] The conclusion that there are states in Sb^{121} at 508 and 573 keV has been made also by F. R. Metzger on the basis of resonance fluorescence results: Bull. Am. Phys. Soc. **8**, 332 (1963); and private communication.
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TABLE V. $E2$ transition speeds for the $d_{3/2} \rightarrow s_{1/2}$ transitions in Te^{121m}, Te^{123m}, and Te^{125m}.

Isotope	Energy keV	$E2/M1$ $=\delta^2$	$\frac{\tau(E2)_{s.p.}}{\tau(E2)_{exp}}$ [a,b] $=E2$ enhancement
Te^{121m}	212.2	0.050 ± 0.003	26
Te^{123m}	159.0	0.0067 ± 0.0011	4.5[c]
Te^{125m}	35.3	0.00035[d]	2[d]

[a] See Ref. 4, Table IV.
[b] The new values of δ^2 for these transitions affect only slightly the $M1$ retardation factors given by Schmorak, Li, and Schwarzschild. These factors become 26 in the case of Te^{121m} and 36 for Te^{123m}.
[c] Schmorak, Li, and Schwarzschild (Ref. 4, Table IV) have pointed out the existence of a discrepancy between the enhancement value 8.9 for Te^{123m} derived from angular correlation results (see Ref. 11) and the value 2.5 derived from Coulomb excitation measurements (see Ref. 12). The disagreement of the enhancement result from this work, 4.5, with the Coulomb excitation result is considerably less drastic.
[d] J. S. Geiger, R. L. Graham, and I. Bergström (private communication). The retardation factor for the $M1$ transition in Te^{125m} has been determined by these investigators to be ~ 50.

approximately 1000.[26] A search for annihilation-radiation coincidences, made by F. R. Metzger,[27] sets an upper limit of 0.1% for the abundance of positrons in the decay of 17-day Te^{121}.

It is of interest to compare the γ-ray lifetime of the 37-keV transition with that of $g_{7/2}$–$d_{5/2}$ transitions in other odd-A antimony isotopes. Unfortunately, there is available, in addition to the result for Sb^{121}, only data for Sb^{123} (Table IV). The $M1$ retardation factor for the Sb^{121} transition, not greatly different from that for Sb^{123}, conforms with the trend of these factors for odd proton transitions.[28]

For the $d_{3/2} \rightarrow s_{1/2}$ transitions in Te^{121m} and Te^{123m}, the $E2$ lifetimes may be calculated from the $E2/M1$ ratios δ^2, obtained in this work and from the known lifetimes (Ref. 4, Table IV). Some unpublished results for Te^{125m} are also included. The relationship used is

$$\tau_\gamma(E2) = 1.44 \tau_{1/2(\text{obs})} (1+\alpha_{\text{tot}})(1+1/\delta^2),$$

where $\tau_\gamma(E2)$ is the mean life for $E2$ photon emission and α_{tot} is the total internal conversion coefficient. The results are shown in Table V. It is apparent that the $E2$ transition speeds in these two cases are enhanced, as is expected to be the case if the particle and phonon excitations are coupled. Calculations of the enhancement have been made by Sorensen[29] and also by Ikegami and Udegawa.[30] Both sets of calculations show enhancements for tellurium with neutron number 71; the Ikegami and Udegawa results would decrease the enhancement with increasing neutron number in the sequence 69, 71, 73, however, the Sorenson results show the opposite trend.

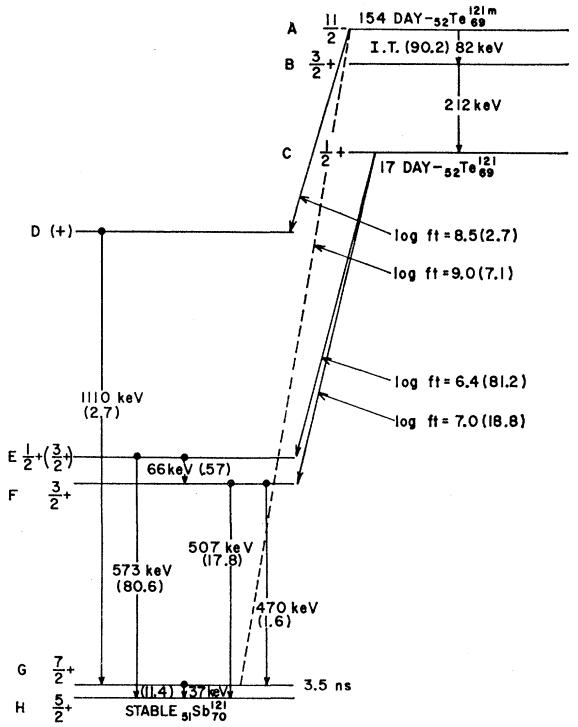

FIG. 8. Decay scheme of Te^{121m} and Te^{121}.

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