O. Dragoun, H. C. Pauli, and F. Schmutzler, Nucl. Data A6, 235 (1969).
[10]G. Alaga, K. Alder, A. Bohr, and B. R. Mottelson, Kgl. Danske Videnskab. Selskab, Mat.-Fys. Medd. 29, No. 9 (1955).
[11]O. Hansen, M. C. Oleson, O. Skilbreid, and B. Elbek, Nucl. Phys. 25, 634 (1961).
[12]S. G. Nilsson, Kgl. Danske Videnskab. Selskab, Mat.-Fys. Medd. 29, No. 16 (1955).
[13]I.-L. Lamm, Nucl. Phys. A125, 504 (1969).
[14]Z. Bochnacki and S. Ogaza, Nucl. Phys. 69, 186 (1965).
[15]O. Prior, F. Boehm, and S. G. Nilsson, Nucl. Phys. A110, 257 (1968).
[16]O. Nathan and S. G. Nilsson, in *Alpha-, Beta-, and Gamma-Ray Spectroscopy*, edited by K. Siegbahn (North-Holland, Amsterdam, 1965), Chap. X.
[17]H. Hübel, R. A. Naumann, and P. K. Hopke, Phys. Rev. C 2, 1447 (1970).
[18]I. Rezanka and H. Ryde, private communication.

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Nuclear Orientation Study of the Decays of ^{126,127,128}Sb†

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Angular distributions have been measured for a number of γ rays emitted by ^{126,127,128}Sb polarized at low temperatures in iron. From the 0–90° anisotropies of the angular distributions, taking the proposed spin values $J=8$ (^{126,128}Sb) and $J=\frac{7}{2}$ (^{127}Sb), the ground-state magnetic moments have been deduced to be: $|\mu(^{126}\text{Sb})| = 1.28 \pm 0.07\ \mu_N$; $|\mu(^{127}\text{Sb})| = 2.59 \pm 0.12\ \mu_N$; $|\mu(^{128}\text{Sb})| = 1.31 \pm 0.19\ \mu_N$. Based on the anisotropies of the ^{127}Te γ rays the following ^{127}Te spin assignments are favored (level energies in keV): $\frac{3}{2}^+$ (0), $\frac{1}{2}^+$ (61), $\frac{11}{2}^-$ (88), $\frac{9}{2}^-$ (341), $\frac{5}{2}^+$ (473), $\frac{7}{2}^-$ (632), $\frac{7}{2}^+$ (686), $\frac{5}{2}^+$ (784), $\frac{9}{2}^-$ (786), $\frac{7}{2}^+$ (924), $\frac{5}{2}^+$ or $\frac{9}{2}^+$ (1077), $\frac{5}{2}^+$ (1142), $\frac{5}{2}^+$ (1290). Based on these spin assignments, $E2/M1$ mixing ratios have been deduced for a number of ^{127}Te γ rays.

I. INTRODUCTION

In a number of recent publications,[1-3] we have reported investigations of the angular distribution of γ rays emitted by ^{122,124,125}Sb nuclei polarized in Fe at low temperatures. Among the parameters which were deduced from these measurements were the angular momentum multipolarities of the β- and γ-radiation fields and the Sb ground-state magnetic moments. We report here similar investigations of the decays of ^{126,127,128}Sb.

II. DECAY SCHEMES

The decays of ^{126,127,128}Sb to levels of ^{126,127,128}Te are illustrated in Figs. 1, 2, and 3, respectively. β and γ radiations and conversion electrons emitted in the decay of the 12.4-day ^{126}Sb have been investigated by Orth, Dropesky, and Freeman,[4] and spin assignments for the higher-lying ^{126}Te states have been proposed by Kiselev *et al.*[5]; the decay scheme of Fig. 1 is based primarily on the latter work. β and γ radiations from the decay of 3.9-day ^{127}Sb were studied by Ragaini, Gordon, and Walters (RGW)[6] and by Takemoto, Iwashita, and Kageyama.[7] The measurement of RGW[6] proposed several spin assignments; the level scheme of Fig. 2 is taken primarily from that work, with additional spin and parity assignments based on the present work included. β and γ spectra from the 8.6-h ^{128}Sb decay were investigated by Kiselev *et al.*,[5,8] and γ-ray coincidence and conversion-electron studies were done by Kerek.[9]

Additional investigations of the ^{126}Te levels have been done through the (d, p) reaction by Graue *et al.*[10] and through the $(\alpha, 2n)$ reaction by Kerek.[11] The ^{127}Te levels have also been studied by Graue *et al.*[12] through the (d, p) reaction. The reaction data are consistent with the level identifications proposed in the above decay studies.

III. EXPERIMENTAL DETAILS

A. Sample Preparation

The Sb isotopes were produced by α-induced fission of U. Following chemical separation of the Sb, a small amount of ^{125}Sb was added; the well-understood decay of ^{125}Sb[3] permits its use as thermometer and also as a verification of the success of the Sb diffusion into the Fe. A quantity of this solution was placed on the surface of a 0.1-mm 99.99%-pure Fe foil, and the Sb was allowed to diffuse into the Fe by annealing at 1100°C for 2 h in a H_2-Ar atmosphere. During annealing, ^{54}Mn and ^{57}Co activities, which had previously been adsorbed onto the walls of the annealing crucible, diffused into the foil. The low-energy γ

rays emitted by ^{57}Co did not interfere with the measurement, and the only effect of the ^{54}Mn γ ray was to increase the background under the Sb γ rays of energies less than 835 keV. Both isotopes provided independent measurements of the sample temperature. Following the annealing, the outer 10% of the foil was etched away to remove surface activities.

The actual sample employed in the experiment was a disk of diameter 6 mm, and at the start of the experiment consisted of the following activities: ^{125}Sb, 3×10^{-2} μCi; ^{126}Sb, 5×10^{-3} μCi; ^{127}Sb, 8×10^{-2} μCi; ^{128}Sb, 3×10^{-3} μCi; ^{54}Mn, 0.4 μCi; ^{57}Co, 2×10^{-3} μCi.

B. Apparatus and Procedure

The sample was maintained in thermal equilibrium at $T = 15$ mK using a ^3He-^4He dilution refrigerator, and was polarized in an external magnetic field of 2–3 kG produced by two pair of perpendicularly oriented superconducting Helmholtz coils. The γ rays were observed using two 40-cm^3 coaxial Ge(Li) detectors oriented at right angles, each detector along the axis of one of the Helmholtz pairs. In this way, simultaneous measurements of the 0 and 90° counting rates could be made, and by alternately powering first one and then the other Helmholtz coil pair, alternate measurements of the 0 and 90° counting rates could be obtained for each detector.

The data were analyzed using two 1024-channel analog-to-digital converters and stored in the memory of a minicomputer, which also controlled the external magnetic-field direction. At the end of each counting period ($\frac{1}{2}$ h for the short-lived ^{128}Sb, 1 to $1\frac{1}{2}$ hours for the longer-lived isotopes), the data were transferred to punched paper tape and the field direction was changed. Approximately 8 days of data were accumulated in this configuration. A typical γ-ray spectrum is illustrated in Fig. 4.

The punched paper tape was converted to punched cards for subsequent computer analysis. The peak counting rates were determined using a weighted-summing procedure, and were corrected for a linear background. The anisotropies of the angular distributions were computed by comparing the peak counting rates for each run with those for the perpendicular field runs immediately previous and subsequent. The procedure involved in this computation has been described previously[13] for the case of the 0–180° asymmetry associated with parity mixing; the application to the 0–90° anisotropy of the present work is straightforward. The normalized χ^2 value was computed as described in Ref. 13 in order to test the statistical spread of the data; values obtained ranged between 0.5 and 2.0, indicating the lack of large nonstatistical fluctuations.

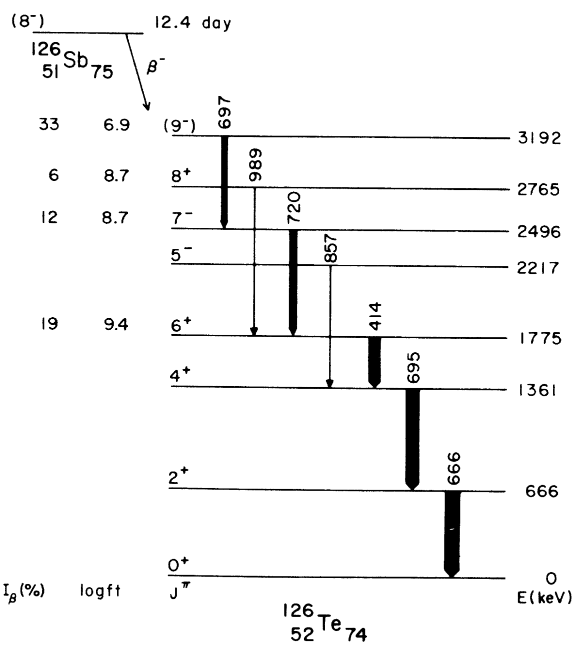

FIG. 1. Partial decay scheme of 12.4-day ^{126}Sb to levels of ^{126}Te, taken from the work of Kiselev *et al.* (Ref. 5). Only those transitions relevant to the present investigation are shown.

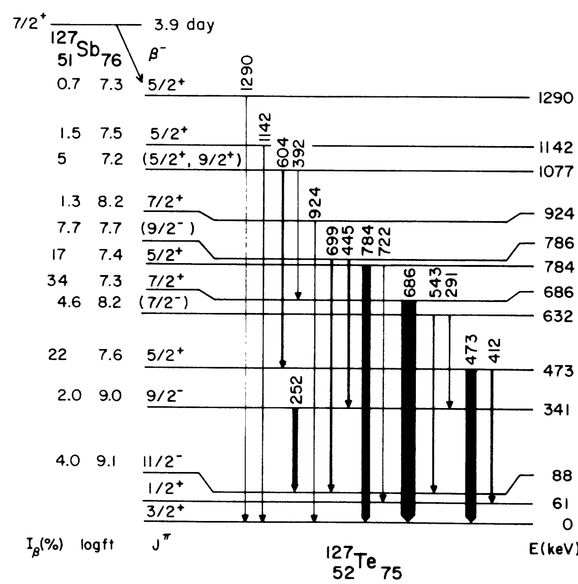

FIG. 2. Partial decay scheme of ^{127}Sb to levels of ^{127}Te, based on the work of RGW (Ref. 6). Spin assignments derived from the present investigation have been included. Only those transitions relevant to the present investigation are shown.

C. Theory

The angular distribution of γ radiation from polarized nuclei is described by

$$W(\theta)=\sum_k Q_k B_k U_k A_k P_k(\cos\theta), \quad (1)$$

where the geometrical factors Q_k correct for the finite-detector solid angle, the orientation parameters B_k describe the orientation of the initial level and depend on the hyperfine splitting $\Delta=\mu H/Jk_B$ and on the temperature, the depolarization coefficients U_k describe the effect of unobserved intermediate β and γ radiations, and the angular-distribution coefficients A_k describe the properties of the observed γ ray. The latter depend on the γ-ray mixing ratio δ, defined according to the convention of Krane and Steffen.[14] The Legendre polynomials P_k are evaluated at the angle θ between the orientation axis and the direction of the γ ray. Equation (1) is normalized such that $Q_0=B_0=U_0=A_0=1$. The various parameters are defined and tabulated by Krane.[15]

The index k is restricted to even values due to the absence of parity-mixing effects in the present experiment, and the relatively small polarizations achieved at 15-mK temperatures cause B_4 to be negligibly small; thus only the $k=2$ terms contribute, and only two independent measurements, the unnormalized 0 and 90° counting rates, are required to extract all the desired nuclear-structure information.

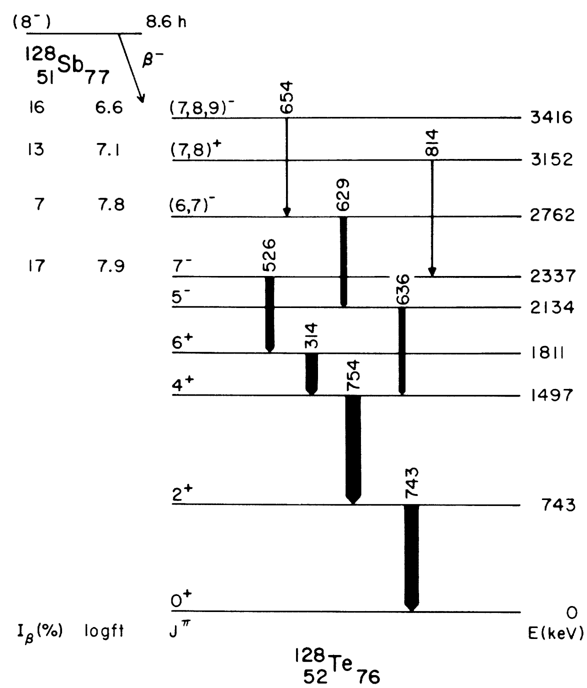

FIG. 3. Partial decay scheme of 8.6-h ^{128}Sb to levels of ^{128}Te, taken from the work of Kerek (Ref. 9). Only those transitions relevant to the present investigation are shown.

IV. RESULTS

The use of Mn, Co, and Sb γ-ray thermometers has previously been discussed by Sites, Smith, and Steyert.[16] For the present work, the mixed $E2/M1$ 428-keV ^{125}Sb γ ray was employed,[3] as well as the pure-$E2$ 835-keV ^{54}Mn and 136-keV ^{57}Co transitions. The ^{125}Sb and ^{54}Mn transitions indicated essentially the same temperature, each with an uncertainty of 0.5 mK; the ^{125}Sb generally indicated perhaps a 1-mK lower temperature. The temperature deduced from the ^{57}Co γ ray likewise was in agreement, but with a larger uncertainty of 1 mK.

As a by-product of the use of ^{57}Co as a thermometer, the $E2/M1$ mixing ratio of the ^{57}Fe 122-keV transition was deduced, by comparison

TABLE I. γ-ray angular distributions from the decays of ^{126,127,128}Sb.

Parent nucleus	γ-ray energy (keV)	$B_2U_2A_2$
^{126}Sb	414	-0.040 ± 0.007 [a]
	666	-0.022 ± 0.008
	695 + 697	-0.033 ± 0.006 [a]
	720	$+0.045\pm0.009$ [a]
	857	$+0.013\pm0.012$
	989	-0.071 ± 0.025
^{127}Sb	252	-0.114 ± 0.004
	291	$+0.129\pm0.021$
	392	$+0.232\pm0.046$
	412	-0.137 ± 0.016 [a]
	445	-0.176 ± 0.011
	473	$+0.226\pm0.002$
	543	-0.052 ± 0.020
	604	-0.123 ± 0.016 [a]
	686	-0.135 ± 0.002
	699	-0.040 ± 0.012 [a]
	722	-0.117 ± 0.044 [a]
	784	-0.008 ± 0.003
	924	-0.102 ± 0.032
	1142	$+0.179\pm0.059$
	1290	$+0.098\pm0.046$
^{128}Sb	314	-0.053 ± 0.017
	526	-0.089 ± 0.040
	743	-0.038 ± 0.015
	754	$+0.010\pm0.020$

[a] Deduced from the compound peak with components from two different isotopes; relative intensities of the components are deduced from the effective decay constant of the peak as well as from intensities of other peaks in the spectrum.

of the 122- and 136-keV angular distributions, with the result

$$\delta(122) = +0.120 \pm 0.004\,,$$

in excellent agreement with the values 0.124 ± 0.001 [17] and 0.120 ± 0.003 [18] obtained in similar investigations.

The deduced values of the product $B_2U_2A_2$ (corrected for detector solid angle) are presented in Table I for the ^{126,127,128}Te γ rays. The results will be discussed individually below.

^{126}Sb. Due to the small polarization obtained for this isotope, the angular-distribution anisotropies were deduced with large relative uncertainties. The interpretation of the data is further complicated by the fact that, for large angular momenta, the various coefficients of Eq. (1) rapidly approach a limiting value; for example, the difference between the A_2 coefficient for an 8^+-6^+ $E2$ transition and that for a 6^+-4^+ $E2$ transition is only 5%, with similar results holding for the B_2 and U_2 coefficients. Thus the present results are not sufficient grounds for accepting or rejecting any of the ^{126}Te spin assignments. The results are in qualitative agreement with the level scheme of Fig. 1, with the $E2$ transitions of the 8^+-6^+-4^+-2^+-0^+ cascade exhibiting nearly equal negative anisotropies, and the $E1$ 7^--6^+ and 5^--4^+ transitions showing anisotropies of the opposite sign, as expected.

Based on the spin assignments of Fig. 1, each of the anisotropies may be used to compute a value of B_2, with the average of the six transitions yielding

$$B_2(^{126}\mathrm{Sb}) = 0.088 \pm 0.009\,,$$

which corresponds to

$$\frac{|\Delta|}{T} = 0.094 \pm 0.005\,,$$

assuming a spin of 8 for the ^{126}Sb ground state. At a temperature of 14.5 mK (deduced from the ^{125}Sb and ^{54}Mn γ-ray anisotropies), and assuming H = 231 kG,[19] we obtain for the magnetic moment of the ^{126}Sb level

$$|\mu(^{126}\mathrm{Sb})| = 1.28 \pm 0.07\ \mu_N\,.$$

The above value of μ again assumes spin 8 for the ^{126}Sb ground state. It should be noted that for large spins, the deduced value of μ is only weakly dependent on the value of the spin. For small Δ/T, B_2 may be approximated as

$$B_2(J) \approx C\mu^2\left(1 + \frac{2}{J} + \cdots\right)^{1/2}, \qquad (2)$$

where C depends on the hyperfine field and on the temperature. Thus for large angular momenta J, B_2 is not strongly dependent on J. For example, if the ^{126}Sb level had spin 7, the deduced value of μ would be reduced by only 1%.

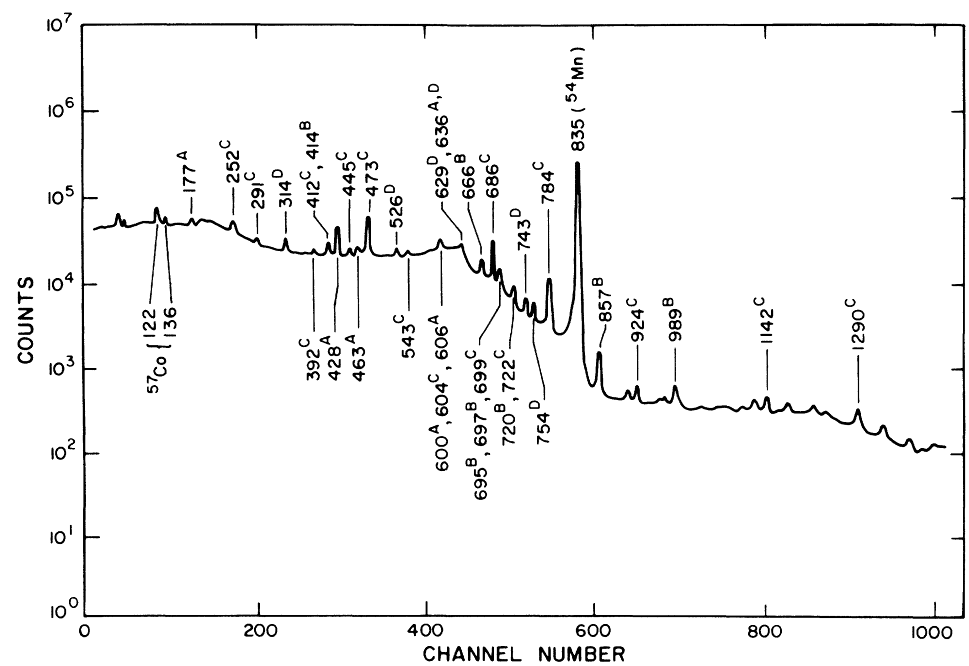

FIG. 4. γ-ray spectrum from the decays of ^{126,127,128}Sb. Peaks labeled with A, B, C, D result from the decays of ^{125,126,127,128}Sb, respectively.

^{128}Sb. The above discussion regarding the dependence of the measured anisotropies on the ^{126}Te spin assignments also holds for the ^{128}Te γ rays. The relative uncertainties of the ^{128}Te γ-ray angular distributions are larger than those of the ^{126}Te transitions, due to the smaller amount of ^{128}Te activity and to its shorter half-life. Negative anisotropies consistent with the 6^+-4^+-2^+-0^+ spin sequence were obtained for the 314-, 754-, and 743-keV γ rays; however a positive anisotropy would be expected for the 526-keV γ ray if it were indeed a 7^--6^+ $E1$ transition. Since this transition seemed to exhibit a substantial negative anisotropy, there is perhaps some evidence for the presence of another transition of the same energy. An additional indication in support of this interpretation was obtained by comparing the radioactive decay constant of the 526-keV peak with that of the other peaks from the ^{128}Sb decay; the 314-, 743-, and 754-keV peaks all decayed with the expected 8.6-h half-life, while the 525-keV peak decayed with a half-life of 11 h, suggesting the presence of a weak (~15%) longer-lived component. It was thus decided to employ only the 314-, 743-, and 754-keV transitions to compute the ^{128}Sb B_2; from the average anisotropy of the transitions (since the anisotropies are expected to be identical) we obtain

$$B_2(^{128}\mathrm{Sb}) = 0.075 \pm 0.025,$$

corresponding to

$$\frac{|\Delta|}{T} = 0.087 \pm 0.013.$$

At a temperature of 16 mK (again based on the ^{125}Sb and ^{54}Mn γ rays), and under the same assumptions as for the case of the ^{126}Sb discussed above, we obtain

$$|\mu(^{128}\mathrm{Sb})| = 1.31 \pm 0.19\ \mu_N.$$

The above deduced value of B_2 corresponds to an anisotropy ($B_2U_2A_2$) of $+0.020 \pm 0.007$ for the 526-keV transition, which is $2\frac{1}{2}$ standard deviations outside of the measured value.

^{127}Sb. In order to determine the B_2 of the ^{127}Sb ground state, the pure-$E2$ 686-keV transition has been employed. The 686-keV level in ^{127}Te is populated by an allowed β decay, as well as by the 392-keV γ ray. The U_2 for the β decay may take values between 1.00 (corresponding to a pure Fermi transition) and 0.810 (corresponding to pure Gamow-Teller). Systematics in this region[3] indicate the dominance of the Gamow-Teller component, as expected for β decays to particle-plus-phonon levels; thus we choose $U_2 = 0.87 \pm 0.06$, an intermediate value with the Gamow-Teller component weighted twice as heavily as the Fermi component. The 392-keV γ-ray feeding introduces a 1% uncertainty into U_2, and may be neglected within the uncertainty of the assumed value. We thus compute, for the ^{127}Sb ground state

$$B_2(^{127}\mathrm{Sb}) = 0.331 \pm 0.024,$$

corresponding to

$$\frac{|\Delta|}{T} = 0.431 \pm 0.020.$$

At a temperature of 14.5 mK (based on the ^{125}Sb and ^{54}Mn γ rays), and assuming $J = \frac{7}{2}$ and $H = 231$ kG, we obtain

$$|\mu(^{127}\mathrm{Sb})| = 2.59 \pm 0.12\ \mu_N.$$

This value is in excellent agreement with systematics of other $g_{7/2}$ levels in the odd-mass Sb isotopes.[20]

Using the above value of B_2, values of U_2A_2 for each of the ^{127}Sb γ rays may be computed, and the results are presented in Table II. From the known spin assignments and branching intensities,[6] values of U_2 were computed for transitions populating the various levels, and hence, values of A_2 for the γ rays were extracted. These values are listed in column 3 of Table II, and the $E2/M1$ mixing ratios derived from the A_2 values are given in Table III. The lack of a measured P_4 term in the present experiments, as well as the lack of internal-conversion or angular-correlation data for the ^{127}Te transitions, makes it impossible to choose between the two values deduced for δ. Those values which are favored on the basis of systematics in this mass region are indicated in Table IV.

TABLE II. Derived angular-distribution parameters of the ^{127}Te γ rays.

γ-ray energy (keV)	U_2A_2	Derived parameter
252	-0.345 ± 0.028	$A_2(252) = -0.462 \pm 0.049$
291	$+0.391 \pm 0.069$	$A_2(291) = +0.54 \pm 0.22$ [a]
392	$+0.701 \pm 0.147$	$A_2(392) = +0.77 \pm 0.17$
412	-0.414 ± 0.057	
445	-0.533 ± 0.051	$A_2(445) = -0.682 \pm 0.142$ [a]
473	$+0.684 \pm 0.050$	$A_2(473) = +0.834 \pm 0.069$
543	-0.158 ± 0.060	
604	-0.372 ± 0.060	$A_2(604) = -0.415 \pm 0.065$
686	-0.407 ± 0.028 [b]	$B_2(^{127}\mathrm{Sb}) = 0.331 \pm 0.024$
699	-0.122 ± 0.036	$A_2(699) = -0.147 \pm 0.047$ [a]
722	-0.353 ± 0.133	
784	-0.023 ± 0.011	$A_2(784) = -0.026 \pm 0.012$
924	-0.309 ± 0.098	$U_2 = 0.66 \pm 0.21$
1142	$+0.543 \pm 0.182$	$A_2(1142) = 0.62 \pm 0.21$
1290	$+0.296 \pm 0.138$	$A_2(1290) = 0.34 \pm 0.16$

[a] Assuming spin assignments derived in the text.
[b] Theoretical value assumed in the analysis.

TABLE III. $E2/M1$ mixing ratios of ^{127}Te γ transitions.

γ-ray energy (keV)	δ [a] $E2/M1$			
252	-0.56 ± 0.10 [b]	or	-1.53 ± 0.24	
291	$+(0.27^{+0.21}_{-0.13})$ [b]	or	$+(6^{+68}_{-3})$	c
392	$+(0.55^{+0.51}_{-0.19})$	or	$+(2.8^{+2.5}_{-1.5})$ if $J^{\pi}(1077)=\frac{5}{2}^{+}$	
	-0.29 ± 0.14	or	-2.1 ± 0.7 if $J^{\pi}(1077)=\frac{9}{2}^{+}$	
445	$+0.4\pm0.2$			
473	-0.29 ± 0.06 [b]	or	-1.56 ± 0.19	
604	0.00 ± 0.07	or	$+1.65\pm0.25$ if $J^{\pi}(1077)=\frac{5}{2}^{+}$	
	pure $E2$		if $J^{\pi}(1077)=\frac{9}{2}^{+}$	
699	-0.21 ± 0.03	or	$-(3.3^{+0.7}_{-0.3})$	c
784	$+0.21\pm0.01$ [b]	or	-11.7 ± 0.9	
1142	$-(0.14^{+0.14}_{-0.11})$	or	$-(2.2^{+0.9}_{-0.6})$	
1290	$+(0.02^{+0.07}_{-0.09})$	or	$-(3.6^{+1.6}_{-0.9})$	

[a] Phase definition of Ref. 14.
[b] Value favored on the basis of systematics.
[c] Assumes spin assignment derived in the text.

The ^{127}Te spin assignments made on the basis of the present work are discussed below for the individual levels.

341 keV. The value $\frac{9}{2}^{-}$ was suggested by RGW[6] based on branching intensities and odd-mass Te systematics. Other values allowed by the branching intensities, $\frac{7}{2}^{-}$ and $\frac{11}{2}^{-}$, are not consistent with the present results, and thus the $\frac{9}{2}^{-}$ assignment is confirmed.

473 keV. Only a $\frac{5}{2}^{+}$ assignment is consistent with the present results for the 412- and 473-keV γ rays.

632 keV. RGW[6] assign possible spins of $\frac{9}{2}^{-}$ or $\frac{11}{2}^{-}$ based on branching intensities and on systematics. The $\frac{7}{2}^{-}$ choice was rejected based on the failure to observe the expected 10^4 enhancement of the transition to the 341-keV level. Since the assumption of this enhancement is somewhat model-dependent, we choose to allow the $\frac{7}{2}^{-}$ possibility for this level.

The present investigation has measured the angular distributions of the 291- and 543-keV transitions which depopulate this level. The 543-keV results would be consistent with any of the spin assignments $\frac{7}{2}^{-}$, $\frac{9}{2}^{-}$, or $\frac{11}{2}^{-}$ with appropriate $E2/M1$ mixing ratios for the $\frac{9}{2}^{-}$ and $\frac{11}{2}^{-}$ choices; for a $\frac{7}{2}^{-}$ choice, the results would be consistent with a pure-$E2$ multipolarity. The results for the 291-keV transition favor the $\frac{7}{2}^{-}$ choice. Poor agreement is obtained for a $\frac{9}{2}^{-}$ spin assignment and the $\frac{11}{2}^{-}$ choice would require that the 291-keV γ ray be either 99.9% $M1$ or else 95% $E2$, and neither of these choices are in good agreement with the magnitudes of $E2/M1$ mixing observed in other transitions in this mass region. We thus favor the $\frac{7}{2}^{-}$ choice, which is in agreement with the

TABLE IV. Comparison of $E2/M1$ mixing ratios of transitions in $^{125,127}Te$.

^{125}Te γ-ray energy (keV)	δ $E2/M1$	^{127}Te γ-ray energy (keV)	δ $E2/M1$
177	-0.624 ± 0.034 [a]	252	-0.56 ± 0.10
204	$+0.47\leq\delta\leq+1.36$ [b]	291	$+(0.27^{+0.21}_{-0.13})$
428	-0.542 ± 0.016 [a]	473	-0.29 ± 0.06
636	$+(0.341^{+0.005}_{-0.006})$ [a]	784	$+0.21\pm0.01$

[a] Reference 3.
[b] Reference 28.

accepted spin assignment of the corresponding ^{125}Te level; the question of this spin is discussed below.

686 keV. The present data permit a $\frac{5}{2}^+$ or $\frac{7}{2}^+$ assignment to this level, but the $\frac{7}{2}^+$ assignment of RGW[6] is strongly favored based on the branching intensities.

784 keV. The present data strongly favor spin $\frac{5}{2}^+$ for this level; this spin was assigned by RGW[6] based on their studies, as well as on (d, p) and (d, t) reaction data.

786 keV. This level was assigned by RGW[6] to be of spin $\frac{7}{2}$ or $\frac{9}{2}$, with no conclusive evidence as to the parity. The present data rule out the possibility of even parity; for either the 445- or 699-keV transitions to be of $E1$ multipolarity would require $A_2 > 0$ which is not observed for either transition. In order for the $\frac{7}{2}^-$ choice to be correct, the $\Delta J = 2$ component would necessarily constitute at least 80% of the intensity of the first-forbidden β decay populating this level. As such large contributions of the $\Delta J = 2$ component are not consistent with systematics, this choice may be discounted and we favor a $\frac{9}{2}^-$ assignment for the 786-keV level.

924 keV. The present data are consistent with the $\frac{7}{2}^+$ assignment of RGW,[6] but do not rule out other assignments. Based on the $\frac{7}{2}^+$ assignment, with a pure $E2$ 924-keV transition, the present data yield

$$U_2 = 0.66 \pm 0.21$$

for the β decay populating this level, indicating that the Gamow-Teller component ($U_2 = 0.81$) is favored somewhat over the Fermi component ($U_2 = 1.00$), in agreement with systematics in this region.

1077 keV. The present results for the 392-keV transition are inconsistent with odd parity for this level, which was assigned as $\frac{5}{2}^\pm$, $\frac{7}{2}^\pm$, or $\frac{9}{2}^\pm$ by RGW.[6] The 392-keV angular distribution is not consistent with the $\frac{7}{2}^+$ choice, but either of the remaining choices ($\frac{5}{2}^+$ or $\frac{9}{2}^+$) are permitted by both the 392- and 604-keV angular distributions.

1142 keV, 1290 keV. These levels were both assigned to be $\frac{5}{2}^+$ by RGW.[6] On the basis of the branching intensities, a $\frac{7}{2}^+$ assignment would also be possible; however, this would require $U_2A_2 = -0.41$, in disagreement with the measured values. We thus confirm the $\frac{5}{2}^+$ assignment for both of these levels.

V. DISCUSSION

The spin-parity assignments of the ^{126,128}Sb ground states are both currently believed to be 8^-,[4,5,8,21] resulting from the coupling of a $h_{11/2}$ neutron with either the $d_{5/2}$ or $g_{7/2}$ proton. The magnetic moment resulting from such a coupling is given by[22]

$$\mu = \tfrac{1}{2}\left\{(g_p + g_n)J + \frac{1}{J+1}(g_p - g_n) \times [j_p(j_p+1) - j_n(j_n+1)]\right\}, \qquad (3)$$

where J is the resultant spin obtained from the addition of the neutron and proton spins j_n and j_p; g_n and g_p are the neutron and proton single-particle g factors ($\mu_{p,n} = g_{p,n} j_{p,n}$), obtained from neighboring odd-mass nuclei. From the compilation of Ref. 20, the magnetic moments of the single-particle states in the odd-mass nuclei are obtained as follows:

$g_{7/2}$ proton: $\mu = 2.55\ \mu_N$ (^{121,123,125,127}Sb),

$d_{5/2}$ proton: $\mu = 3.35\ \mu_N$ (^{119,121}Sb),

$h_{11/2}$ neutron: $\mu = -1.08\ \mu_N$ (^{109,111,113,115}Cd).

Inserting the appropriate spins and g factors into Eq. (3), we compute

$\mu = +1.09\ \mu_N$ ($g_{7/2}$ proton + $h_{11/2}$ neutron),

$\mu = +2.27\ \mu_N$ ($d_{5/2}$ proton + $h_{11/2}$ neutron).

The presently measured experimental values for the ^{126}Sb and ^{128}Sb magnetic moments ($\mu = 1.28 \pm 0.07\ \mu_N$ and $\mu = 1.31 \pm 0.19\ \mu_N$, respectively) indicate a preference for the $g_{7/2}$ state as the major proton component of the 8^- Sb levels. In the neighboring odd-mass Sb nuclei, the $g_{7/2}$ state appears some 300 keV lower in energy than the $d_{5/2}$ state, which supports its choice as the major ^{126,128}Sb ground-state proton component.

It should be noted that Eq. (3) is not sufficiently sensitive to the angular momentum J in order to be able to confirm the 8^- assignments of the ^{126,128}Sb ground states.

As discussed by RGW,[6] the ^{127}Te levels are very similar in structure to the ^{125}Te levels. In Table IV, the presently measured ^{127}Te γ-ray mixing ratios are compared with those of their ^{125}Te counterparts measured previously, and reasonable agreement is obtained, with the appropriate choice of δ from the pair of values obtained in the present work. In particular the 177-keV ^{125}Te and 252-keV ^{127}Te transitions, which deexcite the low-lying $\frac{9}{2}^-$ three-quasiparticle level predicted by Kisslinger,[23] appear to have similar $E2/M1$ mixing ratios; however in both cases the $E2$ multipole does not appear to dominate as strongly as might be expected, since vanishing $M1$ transition probabilities are expected for transitions involving a change of two quasiparticles.

The 632-keV ^{127}Te level has been tentatively assigned by the present work as $\frac{7}{2}^-$, although neither the $\frac{9}{2}^-$ nor $\frac{11}{2}^-$ assignments, favored by RGW,[6] can be eliminated with certainty. The spin of the analogous ^{125}Te 525-keV level has likewise been the subject of some disagreement,[3] with the nuclear orientation experiments of Andrews *et al.*[24] and Stone, Frankel, and Shirley[25] indicating a preference for $\frac{9}{2}^-$ or $\frac{11}{2}^-$, but on the other hand with the observation of a transition to the $\frac{3}{2}^+$ 443-keV level by Mazets and Sergeenkov[26] favoring the $\frac{7}{2}^-$ assignment. The γ-γ angular-correlation data of Inamura[27] likewise showed a preference for the $\frac{7}{2}^-$ assignment, and this data has been recently confirmed by Rots, Silverans, and Coussement[28]; thus a strong preference is indicated for the choice of $\frac{7}{2}^-$ for the ^{125}Te 525-keV level. (It should be noted that the nuclear orientation data of Andrews *et al.*[24] and Stone, Frankel, and Shirley[25] would be consistent with the $\frac{7}{2}^-$ assignment within 2 and $1\frac{1}{2}$ standard deviations, respectively, of the results for the 380-keV angular distribution. Our previous data[3] were consistent with the $\frac{7}{2}^-$ assignment as well as with the $\frac{9}{2}^-$ or $\frac{11}{2}^-$ assignments.) The confirmation of the $\frac{7}{2}^-$ assignment for the ^{125}Te case and the similarity of the ^{125}Te and ^{127}Te level schemes support the $\frac{7}{2}^-$ assignment for the 632-keV level of ^{127}Te. Although RGW[6] rejected this assignment based on a comparison of the probabilities of single-particle γ transitions to the $\frac{9}{2}^-$ and $\frac{11}{2}^-$ levels, we believe that the nature of the 632- and 341-keV levels is not yet well enough understood to draw such a model-dependent conclusion.

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[1]K. S. Krane, J. R. Sites, and W. A. Steyert, Phys. Rev. C 4, 1329 (1971).

[2]J. R. Sites and W. A. Steyert, Nucl. Phys. A156, 19 (1970).

[3]K. S. Krane, J. R. Sites, and W. A. Steyert, Phys. Rev. C 4, 565 (1971).

[4]C. J. Orth, B. J. Dropesky, and N. J. Freeman, Phys. Rev. C 3, 2402 (1971).

[5]B. G. Kiselev, V. N. Levkovskii, O. I. Artem'ev, and L. K. Peker, Izv. Akad. Nauk SSSR Ser. Fiz. 35, 2300 (1971) [transl.: Bull. Acad. Sci. USSR, Phys. Ser. (to be published)].

[6]R. C. Ragaini, G. E. Gordon, and W. B. Walters, Nucl. Phys. A99, 547 (1969).

[7]I. Takemoto, T. Iwashita, and S. Kageyama, J. Phys. Soc. Japan 23, 153 (1967).

[8]B. G. Kiselev, V. N. Levkovskii, and O. I. Artem'ev, Yadern. Fiz. 14, 249 (1971) [transl.: Soviet J. Nucl. Phys. 14, 139 (1972)].

[9]A. Kerek, Nucl. Phys. A185, 497 (1972).

[10]A. Graue, J. R. Lien, H. Vinje, P. B. Vold, and W. H. Moore, Nucl. Phys. A160, 497 (1971).

[11]A. Kerek, Nucl. Phys. A176, 466 (1971).

[12]A. Graue, E. Hvidsten, J. R. Lien, G. Sandvik, and W. H. Moore, Nucl. Phys. A120, 493 (1968).

[13]K. S. Krane, C. E. Olsen, J. R. Sites, and W. A. Steyert, Phys. Rev. C 4, 1906 (1971).

[14]K. S. Krane and R. M. Steffen, Phys. Rev. C 2, 724 (1970).

[15]K. S. Krane, Los Alamos Scientific Laboratory Report No. LA-4677, 1971 (unpublished).

[16]J. R. Sites, H. A. Smith, and W. A. Steyert, J. Low. Temp. Phys. 4, 605 (1971).

[17]R. D. Taylor, private communication.

[18]A. J. Becker and D. C. Cook, Bull. Am. Phys. Soc. 17, 137 (1972).

[19]J. A. Barclay, W. D. Brewer, E. Matthias, and D. A. Shirley, in *Hyperfine Structure and Nuclear Radiations*, edited by E. Matthias and D. A. Shirley (North-Holland, Amsterdam, 1968), p. 902.

[20]V. S. Shirley, in *Hyperfine Interactions in Excited Nuclei*, edited by G. Goldring and R. Kalish (Gordon and Breach, New York, 1971), p. 1255.

[21]M. E. Bunker and H. A. Smith, private communication.

[22]A. de-Shalit and I. Talmi, *Nuclear Shell Theory* (Academic, New York, 1963), p. 56.

[23]L. S. Kisslinger, Nucl. Phys. 78, 341 (1966).

[24]H. R. Andrews, T. F. Knott, B. Greenbaum, and F. M. Pipkin, Phys. Rev. 169, 978 (1968).

[25]N. J. Stone, R. B. Frankel, and D. A. Shirley, Phys. Rev. 172, 1243 (1968).

[26]E. P. Mazets and Yu. V. Sergeenkov, Izv. Akad. Nauk SSSR Ser. Fiz. 30, 1185 (1966) [transl.: Bull. Acad. Sci. USSR, Phys. Ser. 30, 1237 (1966)].

[27]T. Inamura, J. Phys. Soc. Japan 24, 1 (1968).

[28]M. Rots, R. Silverans, and R. Coussement, Nucl. Phys. A170, 240 (1971).