Decay of the 9.4-Min and 8.7-Day Isomers of Sn^{125}

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(Received 19 September 1963)

The decay schemes of the 9.4-min and 9.7-day isomers of Sn^{125} have been studied using scintillation spectrometers and coincidence techniques. Gamma rays of energies 325, 585, 640, 830, 1070, 1390, 1470, 1610, 1720, and 1940 keV with relative intensities 130, 0.75, 0.40, 0.16, 0.17, 1.0, 0.58, 0.28, 0.08, and 0.07, respectively, were observed in the decay of the 9.4-min isomer while the decay of the 9.7-day isomer gives rise to gamma rays of energies 330, 470, 810, 910, 1075, 1165, 1410, 1985, and 2230 keV with relative intensities 0.23, 0.28, 1.0, 0.92, 2.81, 0.09, 0.09, 0.41, and 0.03, respectively. On the basis of the coincidences between the various gamma rays it is concluded that the 9.4-min isomer excites levels in Sb^{125} at 325, 640, 910, 1470, 1720, and 1940 keV, whereas levels at 1075, 1410, 1885, 1985, and 2230 keV are excited in the decay of the 9.7-day isomer. Further evidence in support of these levels from total-absorption gamma spectra is also presented. Plausible spin and parity assignments to these levels have been made on the basis of the log *ft* values of the beta groups feeding these levels and also their decay modes.

I. INTRODUCTION

SEVERAL workers have studied the radiations in the decay of 9.4-min and 9.7-day isomers of Sn^{125}. The most recent and detailed investigation of the decay schemes of these isomers is due to Burson *et al.*[1] These authors have used scintillation spectrometers and coincidence techniques with a multichannel analyzer. They report gamma rays of energies 342, 468, 811, 904, 1068, 1410, and 1970 keV with relative intensities 9, 10, 20, 18, 73, 3, and 24, respectively, in the decay of the 9.7-day isomer. The coincidence relationships between these gamma rays have been explained by assuming levels in Sb^{125} at 1070, 1410, 1880, and 1970 keV. In the decay of the 9.4-min isomer, gamma rays of energies 326, 640, 1070, and 1390 keV with relative intensities 99.7, 0.3, 0.3, and 1.9, respectively, have been reported. To explain the observed coincidences among these gamma rays, the authors have proposed levels at 326, 640 or 1070, and 1720 keV. In the present work the decay schemes of the Sn^{125} isomers have been reinvestigated in order to get more information about the levels in Sb^{125} fed in these decays.

II. EXPERIMENTAL PROCEDURE AND RESULTS

A. The 9.4-min Activity

1. Source Preparation

The 9.4-min activity was obtained by irradiating about 3 mg of enriched Sn^{124} (96%) in the form of SnO_2 for periods of about 5 min in a flux of $\simeq 10^{12}$ neutrons/cm^2-sec at the Apsara reactor. The observations were started within 2 min after the irradiations and it was observed that the Sb^{125} activity did not build up enough to cause any interference. The sources for the study of the gamma-spectrum and gamma-gamma coincidences were made by sandwiching the irradiated SnO_2 between two aluminum strips $\frac{1}{16}$ in. thick.

[1] S. B. Burson, J. M. Le Blanc, and D. W. Martin, Phys. Rev. **105**, 625 (1957).

2. Gamma-Ray Spectrum

The gamma-ray spectrum was studied with a 3-in.-diam×3-in.-thick NaI(Tl) crystal coupled to a DuMont 6363 photomultiplier. The resolution of this integral assembly was 8.5% for the 662-keV gamma ray of Cs^{137}. The spectra were recorded on a Nuclear Data 512 channel analyzer. An aluminum absorber approximately 900 mg/cm^2 thick was used for absorbing the beta particles. The gamma spectrum taken with the source at a distance of 15 cm from the crystal showed a very intense photopeak due to a 325-keV gamma ray and a weak photopeak due to a 1390-keV gamma ray. In order to see whether any other weak gamma rays were also present, the source was placed almost in contact with the crystal with a 6-mm-thick lead absorber in-between to reduce the intensity of the 325-keV gamma ray. The gamma spectrum obtained in this way was analyzed in the usual manner by subtracting out the contributions due to individual gamma rays. The standard line shapes for this purpose were obtained by recording under similar conditions of geometry the gamma spectra of Ce-Pr^{144}, La^{140}, Na^{22}, Zn^{65}, Mn^{54}, Cs^{137}, Au^{198}, and Cr^{51}. The gamma spectrum along with the line shapes as they were fitted in the analysis is reproduced in Fig. 1. It is seen that apart from the intense 325-keV gamma ray, other weak gamma rays of energies 585, 640, 830, 1070, 1390, 1470, 1610, 1720, and 1940 keV are also present. Of these, the 585-, 830-, 1470-, 1610-, 1720-, and 1940-keV gamma

TABLE I. Relative intensities of gamma rays of 9.4-min Sn^{125}, corrected for photopeak efficiency and absorption in lead.

Gamma-ray energy (keV)	Relative intensity	Gamma-ray energy (keV)	Relative intensity
325±5	130±20	1390±10	1.0
585±10	0.75±0.11	1470±10	0.58 ±0.09
640±10	0.40±0.06	1610±10	0.28 ±0.04
830±10	0.16±0.03	1720±15	0.085±0.02
1070±10	0.17±0.03	1940±15	0.072±0.014

rays have not been reported earlier. It was ascertained that all these gamma rays are due to the 9.4-min activity of Sn^{125} by following their decay over a period of three half-lives. The photopeak at 150 keV was seen to decay with a longer half-life of 40 min and was attributed to the presence of Sn^{123}. Table I gives the relative intensities of these gamma rays, corrected for the photoefficiency and the absorption in lead. The contributions due to genuine and random summing have been taken into account. The corrections due to these were found to be small except in the case of the intensity of the 640-keV gamma ray. In order to verify that the correction for absorption in the lead absorber did not introduce any large errors, the intensity of the 1390-keV gamma ray relative to that of the 325-keV gamma ray was also calculated from the gamma spectrum taken with the source at a distance of 15 cm without any absorber. This intensity was found to agree with the one listed in Table I within 5%, showing that there was no error due to the correction for absorption.

3. Gamma-Gamma Coincidence Measurements

In order to study the coincidences between various gamma rays, two scintillation spectrometers consisting of 3-in.-diam×3-in.-thick NaI(Tl) crystals coupled to DuMont 6363 photomultipliers were used. A fast-slow

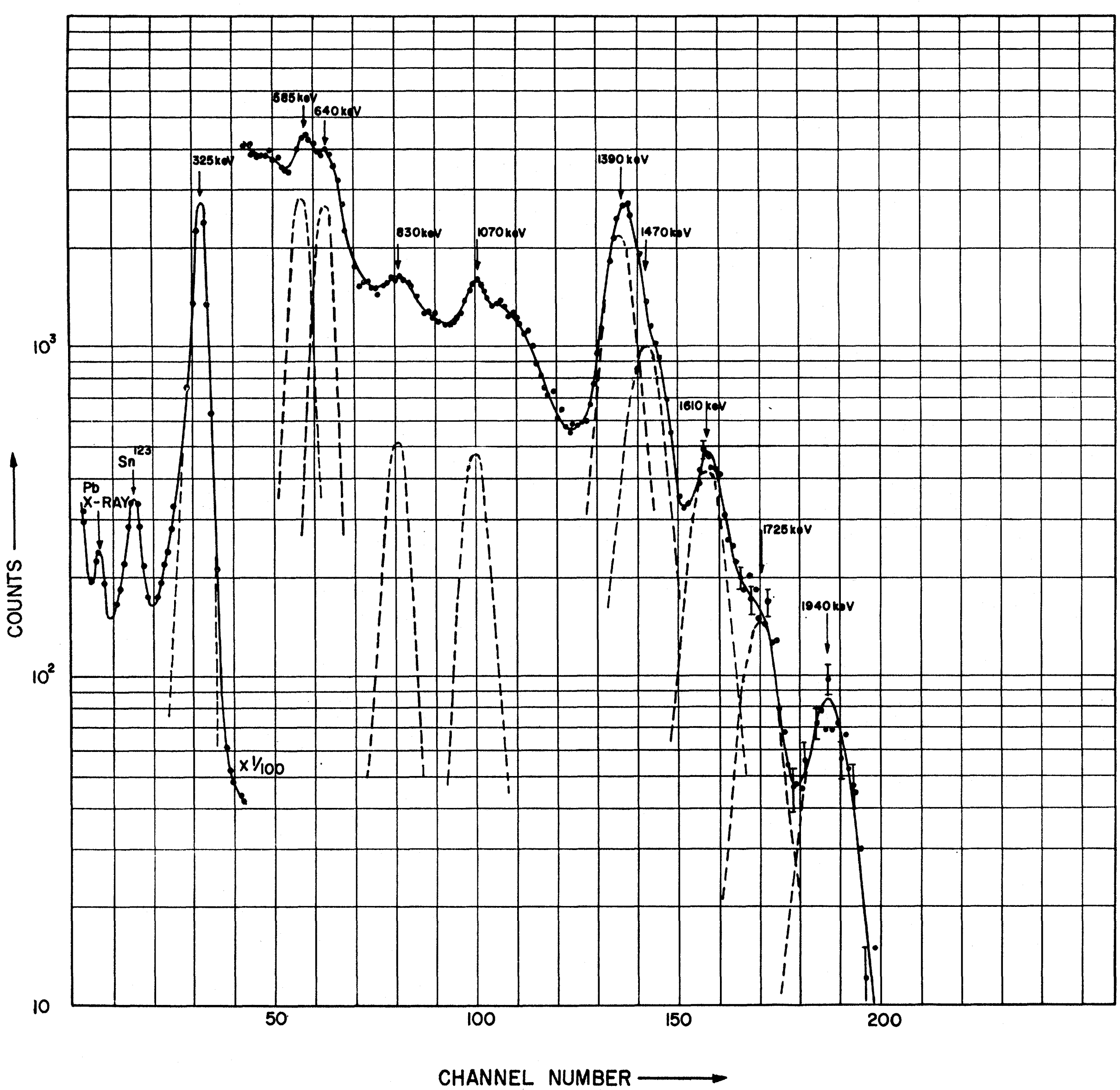

FIG. 1. Gamma spectrum of Sn^{125} (9.4 min).

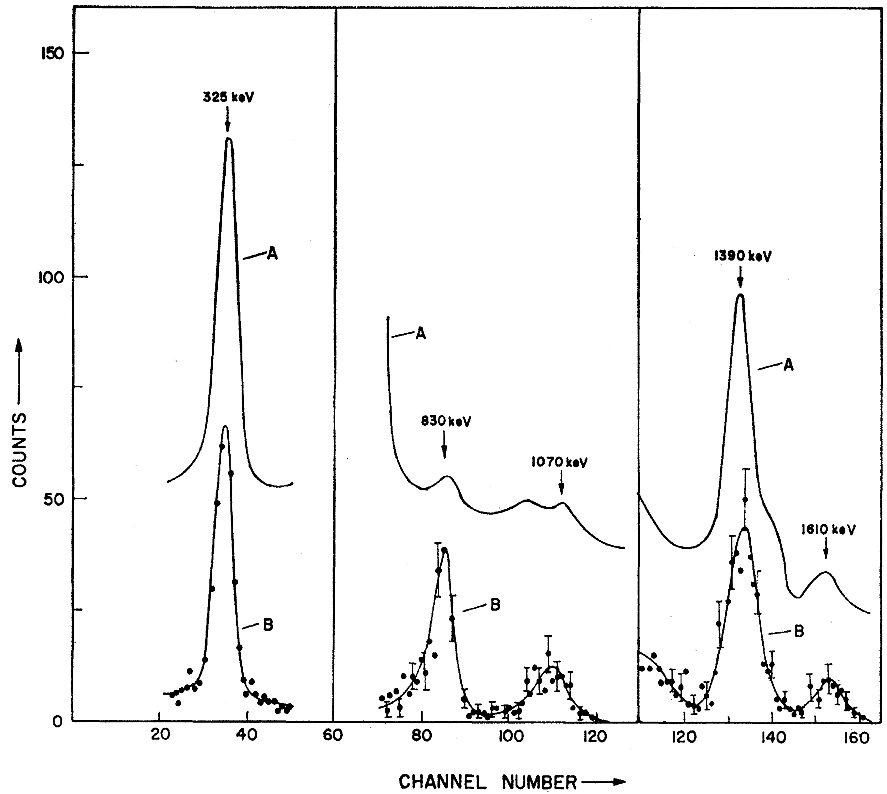

FIG. 2. Gamma spectrum in coincidence with (i) 585 keV in the gate, (ii) 640 keV in the gate, (iii) 325 keV in the gate. A–singles spectrum, and B–coincidence spectrum in each case.

coincidence setup, making use of the crossover pick-off principle[2] and having a resolving time $2\tau=0.2\ \mu$sec was utilized. The coincidence spectra with the photopeaks of various gamma rays in gate were recorded on the 512 channel analyzer. The crystals were placed face-to-face with suitable anti-Compton shielding in-between to avoid spurious coincidences due to back scattering. The intensity of the 325-keV gamma ray was reduced with the help of a 6-mm-thick lead absorber. The decay of the various photopeaks in the coincidence spectra was followed over a period of two half-lives in order to confirm that they were due to the 9.4-min Sn^{125} activity. In order to correct for the Compton contributions of high-energy gamma rays which are included in the gate, coincidence spectra were also recorded with the gate shifted away from the photopeaks. The coincidence

TABLE II. Gamma-gamma coincidence results of 9.4-min Sn^{125}.

Gate (keV)	Gamma rays in coincidence (keV)
325	585, 1390, 1610
585	325
640	830, 1070
830	640
1390	325

[2] E. Fairstein, Oak Ridge National Laboratory Report No. 2480, 1958 (unpublished).

spectra were also corrected for chance coincidences. Some of the coincidence spectra obtained in this way are shown in Fig. 2. The results of all the coincidences are summarized in Table II. The coincidences observed between the 580-, 1390-, and 1610-keV gamma rays and the 325-keV transition indicate the presence of levels at 910, 1720, and 1940 keV. The last two levels can also explain the observed gamma rays of energies 1720 and 1940 keV as crossover transitions from these levels. The 1720-keV level has also been proposed by the earlier workers[1] to explain the coincidence between 640- and 1070-keV gamma rays. They could not, however, establish whether the cascade was through a level at 1070 or 640 keV. The fact that the 830-keV gamma ray is also in coincidence with the 640-keV gamma ray removes this ambiguity and shows that there are levels in Sb^{125} at 640 and 1470 keV. The observed 1470-keV gamma ray can then be interpreted as a crossover transition from the latter level. It is thus clear that all the observed gamma rays and the coincidences among them can be understood by assuming levels in Sb^{125} at 325, 640, 910, 1470, 1720, and 1940 keV.

4. *Total Absorption Gamma Spectrum*

In order to confirm the presence of the proposed new levels at 910, 1470, and 1940 keV, the gamma spectrum was studied in almost 4π geometry by introducing the source in the $\frac{1}{4}$-in.-diam$\times 1\frac{1}{2}$-in.-deep well of the

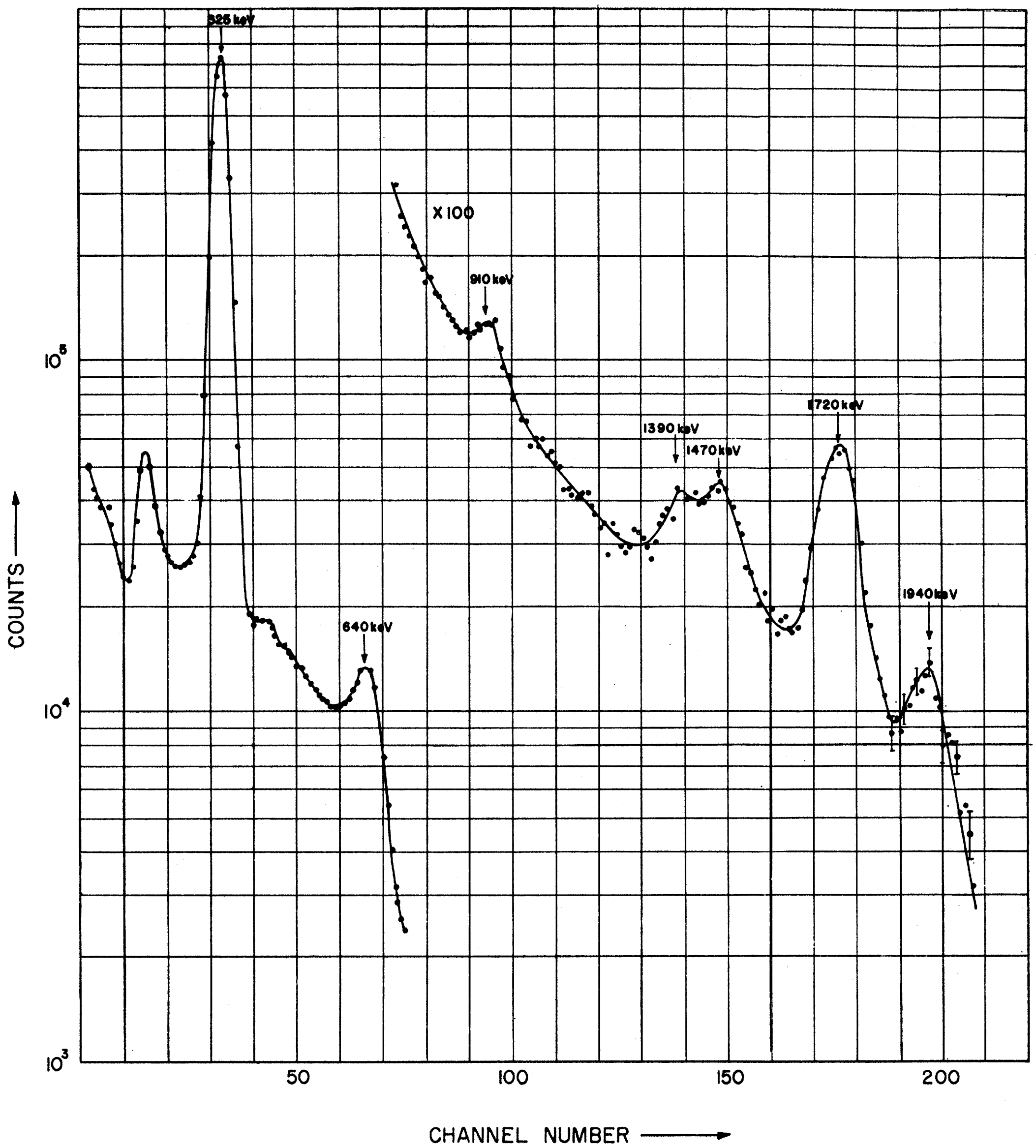

FIG. 3. Total absorption gamma spectrum of Sn^{125} (9.4 min).

3-in.-diam×3-in.-thick NaI(Tl) crystal. The beta particles were absorbed with a copper absorber. In such total absorption gamma spectra, coincident gamma rays sum up to a large extent, giving rise to distinct sum peaks. Levels having beta feedings can easily be identified from the sum peaks corresponding to them. Figure 3 shows such a spectrum for the 9.4-min activity of Sn^{125}. The sum peaks due to the levels at 325, 640, 910, 1470, 1720, and 1940 keV can clearly be seen. The decay of all these peaks was studied over a period of three half-lives to confirm that they were all due to the 9.4-min activity of Sn^{125}. The intensity of the 1390-keV photopeak is very much reduced here as it sums up considerably with the 325-keV gamma ray to give an intense sum peak at 1720 keV. Similarly, the peak at 1470 keV is better resolved than in the singles gamma spectrum which suggests summing due to the 640–835-keV cascade and a beta feeding to the 1470-keV level. The effect of the nonlinear response of the NaI(Tl) crystal has been taken into account while assigning these energies to the sum peaks.[3] The intensities of the sum peaks at 1720 and 1940 keV relative to the intensity of the 325-keV photopeak agree very well with the values expected from the relative intensities given in Table I. Thus, the total absorption spectrum lends further support to the proposed levels, the relative

[3] H. G. Devare and P. N. Tandon, Nucl. Instr. **22**, 253 (1963).

TABLE III. Beta transition data for 9.4-min Sn^{125}.

Beta end point (keV)	Level fed (keV)	Relative intensity (%)	log *ft*
2030	325	98	5.4
1715	640	0.06	8.4
1445	910	0.58	7.2
885	1470	0.17	6.7
630	1725	0.96	5.5
410	1940	0.27	5.4

intensities of the gamma rays and the coincidences observed.

5. *Beta Branchings and log ft Values*

The beta spectrum of the 9.4-min activity was studied with a $1\frac{1}{2}$-in.-diam × 1-in.-thick anthracene crystal coupled to an EMI 9536A photomultiplier. The end point of the beta spectrum was found to be 2030±40 keV. The beta spectrum in coincidence with the 325-keV gamma ray showed the same end-point energy indicating that this beta group feeds the 325-keV level. No attempt was made to find out other beta groups by analyzing the beta spectrum, as it was realized that such beta groups would be extremely weak in intensity. The intensities of the beta groups feeding other levels were, therefore, estimated from the relative intensities of the gamma rays. Table III summarizes the data about beta transitions in the decay of 9.4-min Sn^{125}. The end-point energies of the various beta groups mentioned in the table are obtained directly from the energies of the levels which they feed and the experimentally found value of the end-point energy of the beta group feeding the 325-keV level.

6. *Decay Scheme*

The decay scheme of the 9.4-min activity of Sn^{125}, based on the results of the present investigations, is shown in Fig. 4. The level at 1720 keV has been proposed by earlier workers[1] also. The ambiguity about the position of a level either at 640 or 1070 keV suggested by these workers has now been removed, and the present work supports the level at 640 keV. Besides these, three new levels have been proposed at 910, 1470, and 1940 keV. Strong evidence for these levels has been obtained from the analysis of the gamma spectrum, gamma-gamma coincidences and the total-absorption gamma spectrum, as has been shown in the subsections 2, 3, and 4 above. On the basis of shell-model considerations, the ground state of Sb^{125} is expected to be $g\ 7/2$, and the isomers of Sn^{125} can be $d\ 3/2$ and $h\ 11/2$. The spin and parity assignment of $\frac{3}{2}+$ to the 9.4-min activity has been made on the basis of the absence of any beta feeding to the ground state of Sb^{125}. The 325-keV level is expected to have a $d\ 5/2$ character according to the shell model, and the observed log *ft* value for the beta transition to this level is consistent with such an assignment. The spin and parity assignments to the other levels have been made consistent with the log *ft* values of the beta groups feeding these levels and the gamma transitions arising from these levels. Thus the beta groups feeding the 1720- and 1940-keV levels have log *ft* values corresponding to allowed transitions indicating $\frac{1}{2}+$, $\frac{3}{2}+$, or $\frac{5}{2}+$ as the possible spin and parity

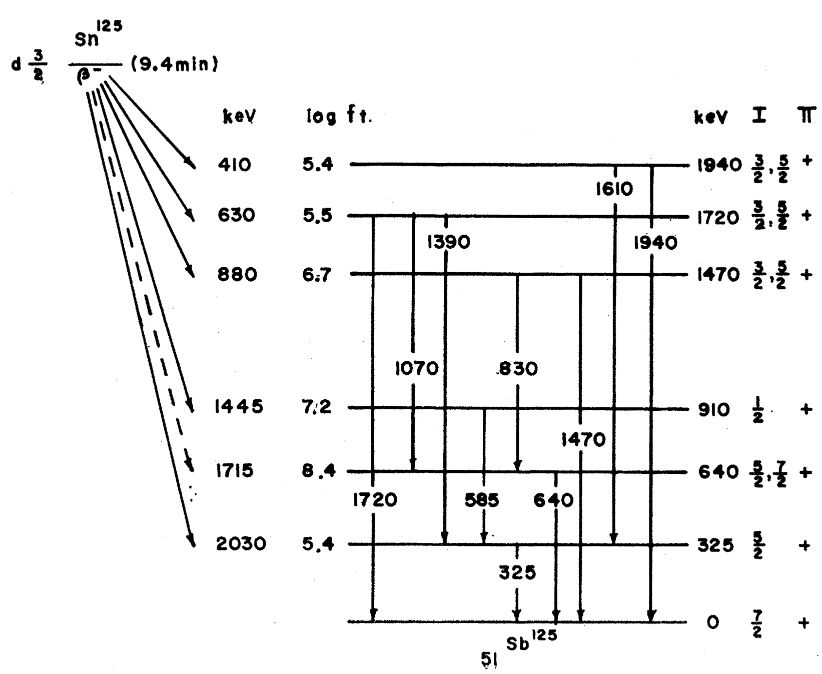

FIG. 4. Decay scheme of the 9.4-min isomer of Sn^{125}.

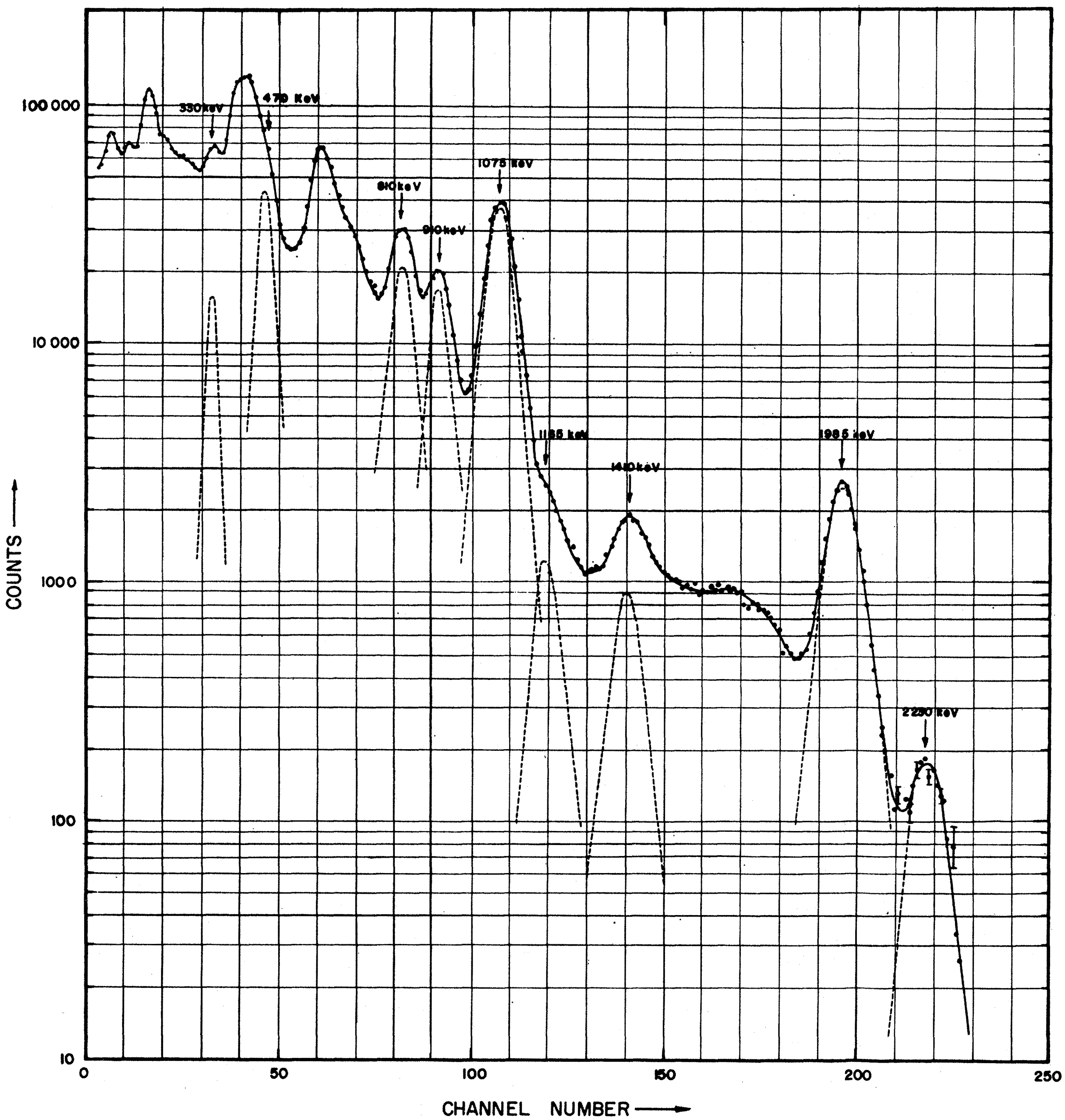

FIG. 5. Gamma spectrum of Sn^{125} (9.7 day).

assignments. Of these, the possibility $\frac{1}{2}^+$ is ruled out on the basis of the ground-state transitions from these levels. Similarly, the 1470-keV level is also assigned the spin and parity $\frac{3}{2}^+$ or $\frac{5}{2}^+$ though the log *ft* value of the beta feeding to this level is rather high for an allowed transition. The character of the 910-keV level is most probably $\frac{1}{2}^+$ in view of the absence of any transition to the ground state. However, the log *ft* value for the beta group feeding this level also is too high for an allowed transition. The beta feeding to the 640-keV level is very small and an assignment of $\frac{7}{2}^+$ for its spin and parity would be consistent with this, though the possibility $\frac{5}{2}^+$ cannot be completely ruled out.

B. The 9.7-day Activity

1. Source Preparation

The 9.7-day activity of Sn^{125} was produced by irradiating about 15-mg of SnO_2 enriched in Sn^{124} (96%) in the DIDO reactor, Harwell, in a flux of 10^{14} neutrons/

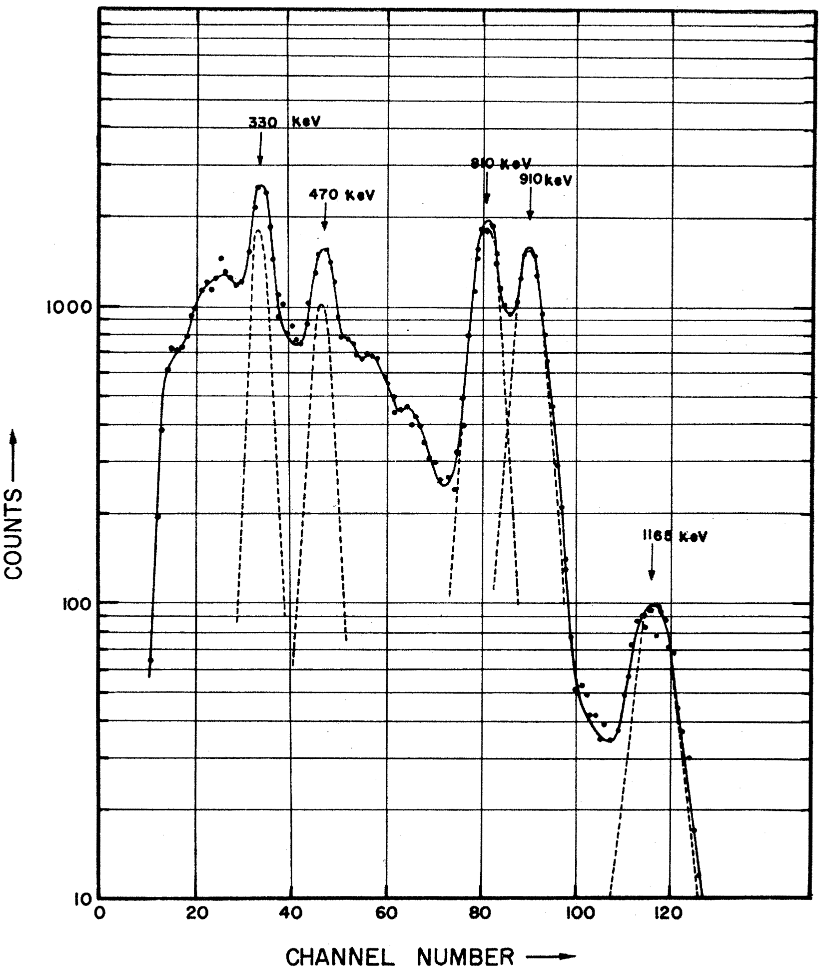

FIG. 6. Gamma spectrum in coincidence with the 1075-keV transition.

cm²-sec for a period of 3½ weeks. Chemical separation was performed to remove the dominant activity of Sb^{125} which is formed mainly by the decay of the 9.4-min isomer. This chemical separation was found to be rather difficult because of the chemical form in which the enriched sample was obtained and so only a partial separation was possible.

2. *The Gamma Spectrum*

The gamma spectrum was studied in the same way as has been already described above. The source-to-crystal distance in this case was 15 cm, and a Perspex absorber of 1 cm thickness was used to absorb the beta particles. The gamma spectrum along with the standard line shapes as they were fitted in the analysis is reproduced in Fig. 5. On the basis of this analysis, gamma rays of energies 330, 470, 810, 910, 1075, 1165, 1410, 1985, and 2230 keV have been assigned to the decay of 9.7-day Sn^{125} as the intensities of these gamma rays decayed with this half-life. In the case of 330- and 470-keV gamma rays, correction was applied for the contribution from Sb^{125} by taking into account the relative intensities of the gamma rays of Sb^{125}.[4] An estimate of the contribution due to the bremsstrahlung produced by absorption of the intense beta transition to the ground state was made by recording the bremsstrahlung spectrum of P^{32} in similar geometry. The

TABLE IV. Relative intensities of gamma rays of (9.7-day) Sn^{125} corrected for Sb^{125} contribution, and normalized to a value of 100 for 810-keV gamma ray.

Gamma-ray energy (keV)	Singles spectrum	Spectrum in coincidence with gamma ray of energy 1075 keV
330±10	0.23 ±0.06	0.28 ±0.05
470±10	0.28 ±0.06	0.25 ±0.05
810±10	1.0	1.0
910±10	0.92 ±0.14	0.94 ±0.14
1075±10	2.81 ±0.42	
1165±15	0.093±0.014	0.087±0.014
1410±10	0.092±0.014	
1985±10	0.407±0.06	
2230±20	0.031±0.005	

[4] R. S. Narcisi, thesis, Harvard University, 1959 (unpublished).

TABLE V. Gamma-gamma coincidence results of 9.7-day Sn^{125}.

Gate (keV)	Gamma rays observed in coincidence (keV)
1165	1075
1075	1165, 910, 810, 470, 330
910	1075
810	1075
470	1410, 1075, 330
330	470, 1075

relative intensities of the gamma rays after correcting for any summing effects are given in Table IV, which also gives the relative intensities obtained from the gamma spectrum in coincidence with the 1075-keV gamma ray as described below. Except for the 1165- and 2230-keV gamma rays, all the other gamma rays have been reported earlier.[1]

3. *Gamma-Gamma Coincidence Measurements*

The coincidence spectra with various gamma rays in the gate were recorded with the same setup as described above, except that a Bell-Graham-type fast-slow coincidence circuit with a resolving time $2\tau=0.13$ μsec was used. The crystals were kept at right angles to each other with a source-to-crystal distance of 8 cm, and a suitable anti-Compton shield was used to avoid spurious coincidences. Figure 6 shows the gamma spectrum in coincidence with the 1075-keV gamma ray. The spectrum was corrected for chance coincidence and analyzed in the usual way. The relative intensities obtained from this analysis are also included in Table IV. It is seen that there is a good agreement between the relative intensities found from the singles and coincidence gamma spectra. In the low-energy region, the relative intensities from the coincidence spectrum are more reliable as the interference from Sb^{125} is completely suppressed. Apart from the other coincidences which have already been reported by earlier workers,[1] the 1075-keV gamma ray shows a coincidence with the 1165-keV gamma ray also. This suggests a new level at 2230 keV which is further supported by the presence of the 2230-keV gamma ray, which can then be interpreted as a transition to the ground state from this level. The 1165–1075-keV coincidence was also checked by taking the 1165-keV gamma ray in the gate. This coincidence spectrum is reproduced in Fig. 7 and shows only the 1075-keV photopeak. Coincidence spectra were also recorded with the photopeaks of the other gamma rays in the gate and the results are shown in Table V. These coincidence measurements confirm the results of Burson *et al.*[1]

4. *Total Absorption Gamma-Ray Spectrum*

In order to confirm the existence of the level at 2230 keV, and also to check the relative intensities of the gamma rays, the gamma spectrum of the 9.7-day

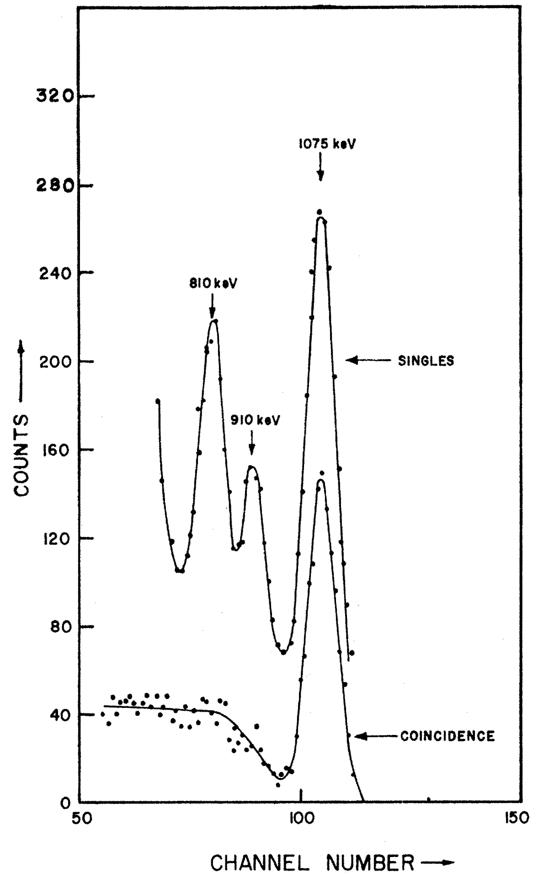

FIG. 7. Gamma spectrum in coincidence with 1165-keV region in the gate.

Sn^{125} was recorded in 4π geometry as already described before. This is reproduced in Fig. 8, and a peak at 2230 keV and a broad peak at about 1900 keV are clearly seen. An analysis of this high-energy region of the spectrum was made using as standard line shapes the photopeak of the 2180-keV gamma ray from a Ce-Pr^{144} source and the 2300-keV sum peak from a Na^{22} source. The relative intensities of the 2230-, 1985-, and 1885-keV sum peaks were seen to be in very good agreement with the sum peak intensities calculated from the relative intensities of the gamma rays participating in the cascades. This serves as a further check on the correctness of the relative intensities of the gamma rays as given in Table IV. The total absorption gamma-ray spectrum also establishes beyond doubt the existence of the 2230-keV level.

5. *Sum-Coincidence Measurements*

The de-excitation of the 2230-keV level was further studied by the sum-coincidence technique[5,6] in order

[5] A. M. Hoogenboom, Nucl. Instr. 3, 57 (1958).
[6] S. Jha, H. G. Devare, M. Narayana Rao, and G. C. Pramila, Proc. Indian Acad. Sci. 50, 303 (1959).

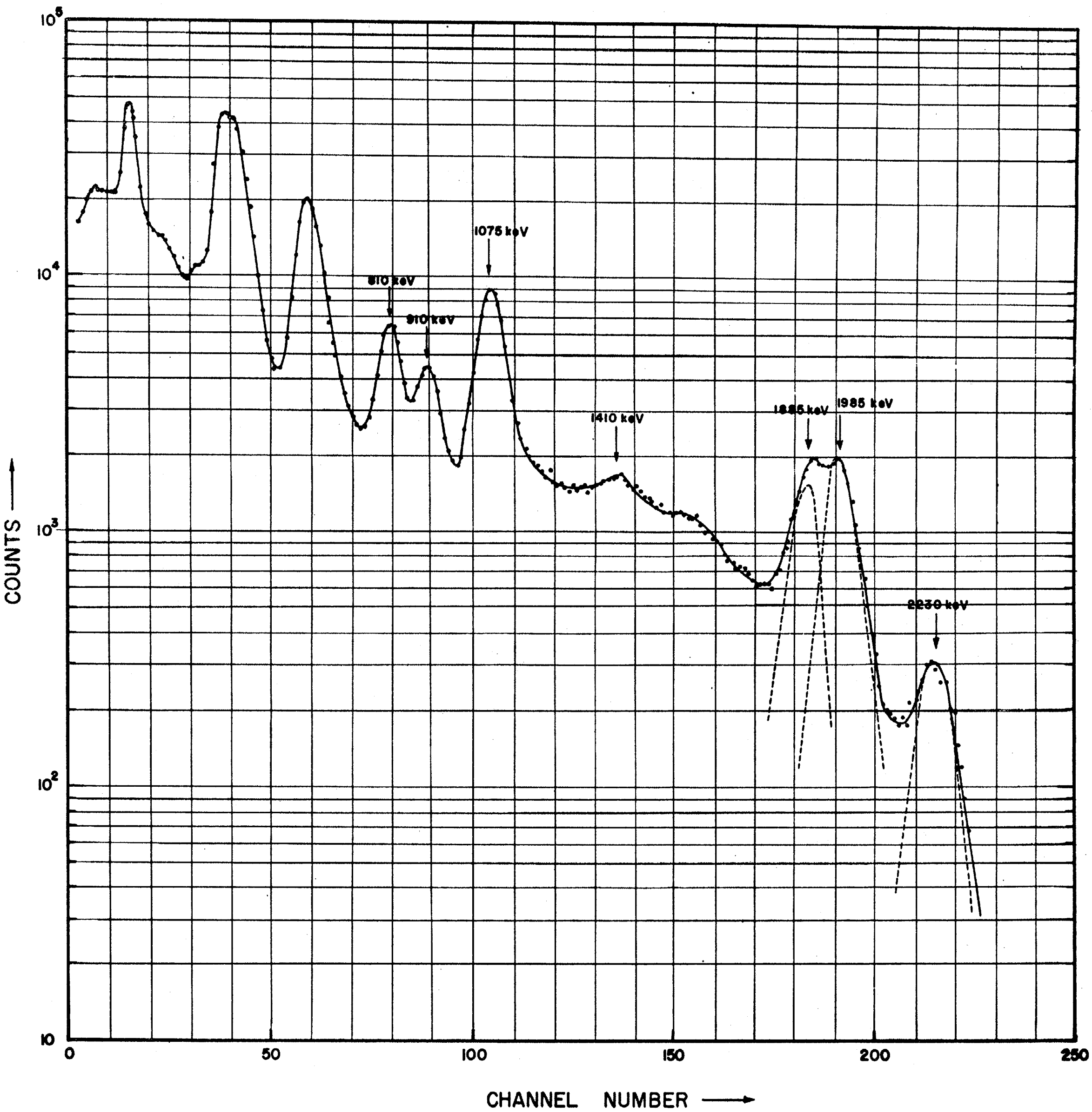

FIG. 8. Total absorption gamma spectrum of Sn^{125} (9.7 day).

to see whether this level has decay modes other than the 1165–1075-keV cascade and the 2230-keV cross-over transition. The sum-coincidence spectrum is reproduced in Fig. 9A. It is clear that the 1165–1075-keV cascade is the chief mode of de-excitation apart from the 2230-keV cross-over transition. The other gamma rays of energies 810, 910, 470, 330 keV do not participate in the decay of this level. For comparison, the sum-coincidence spectrum with the higher part of the 1985-keV sum peak in the gate is also shown in Fig. 9B. This shows that the 1985-keV level deexcites only by the 910–1075-keV cascade.

6. Beta-Branchings and log ft Values

In order to calculate the relative intensities of the beta groups feeding the various levels, the intensity of the beta transition to the ground state was assumed to be 95%.[7] The relative intensities could then be calculated from the relative intensities of the gamma rays. The end-point energies of the beta groups were inferred from the energies of the levels they fed, assuming the end-point energy of the beta group to the ground state to be 2350 keV.[7] The relative intensities and the log *ft* values found this way are given in Table VI. It may be

[7] R. W. Hayward, Phys. Rev. **79**, 409 (1950).

TABLE VI. Beta transition data for 9.7-day Sn^{125}.

Beta end point (keV)	Level fed (keV)	Relative intensity (%)	log ft
2350	Ground state	95	8.8
1275	1075	0.8	10.1
940	1410	0.2	9.9
465	1885	1.9	7.9
365	1985	1.9	7.6
120	2230	0.2	7.0

pointed out here that these relative intensities differ considerably from those given by Burson *et al.*[1] This is so because the relative intensities of gamma rays on which the beta branchings are based, are found in the present work to be different from those reported in Ref. 1.

7. *Decay Scheme*

The decay scheme of the 9.7-day Sn^{125} is shown in Fig. 10. This is similar to the one proposed by Burson *et al.*, except for the 2230-keV level which has been proposed by us. The presence of this level is supported by the results of the analysis of the gamma spectrum, gamma-gamma coincidences, total-absorption gamma spectrum and sum-coincidence spectrum. The spin and parity assignment for the 9.7-day Sn^{125} should be $h\ 11/2$ according to shell model, since the 9.4-min activity has already been identified as the $d\ 3/2$ isomer. The log ft value of the beta transition to the ground state of Sb^{125} is then consistent with its first forbidden unique character. The large log ft values for the beta transitions to the 1075- and 1410-keV levels also point to a spin and parity assignment of $\frac{7}{2}^+$ to these levels. The beta transitions to the 1985- and 2230-keV levels may be

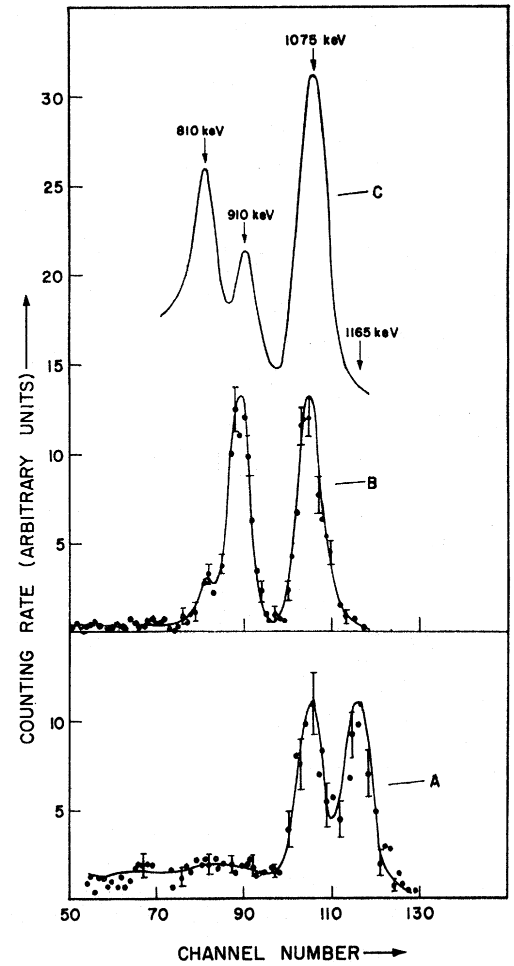

FIG. 9. Sum coincidence spectrum with (A) 2230-keV sum peak, and (B) 1985-keV sum peak in gate. (C) Singles spectrum.

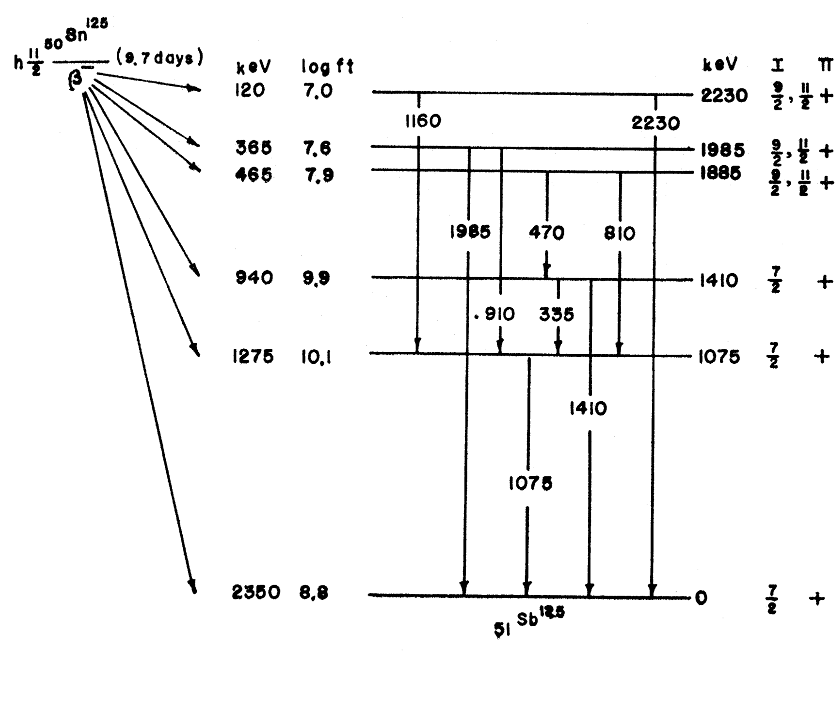

FIG. 10. Decay scheme of the 9.7-day isomer of Sn^{125}.

considered to be first forbidden transitions on the basis of their log *ft* values. Their spin and parity can, therefore, be $\frac{9}{2}^+$ or $11/2^+$, the third possibility of $13/2^+$ being ruled out because of the observed transitions to the ground state from these levels. The situation about the spin and parity of the 1885-keV level is a little more uncertain because the log *ft* value of the beta group feeding this level is rather high for a first forbidden transition but slightly low for a first forbidden unique transition. Moreover, there has not been observed any transition to the ground state from this level though there are transitions both to the 1075- and 1410-keV levels. In view of the fact that both of these levels are likely to have spin and parity $\frac{7}{2}^+$ similar to the ground state, it is difficult to understand these transitions. A tentative assignment of $\frac{9}{2}^+$ or $11/2^+$ has been made in this case, assuming that the transition to the ground state is hindered due to some other reasons which are, as yet, not clear.

III. DISCUSSION

The present investigations show the presence of several new levels in Sb^{125} which are fed in the decay of the isomers of Sn^{125}, besides confirming those proposed by earlier workers. However, it is observed that the relative intensities of gamma rays found in this work are not in very good agreement with those of Burson *et al.* The reason for this discrepancy may be the rather peculiar geometry used by these workers. For our calculations of relative intensities, we have used a source-to-crystal distance of 15 cm without any collimator and have used the values of total efficiency and peak-to-total ratio given by Heath.[8] Even in the case of low-intensity gamma rays in the high-energy region, studied with a lead absorber, it was verified that the absorption correction did not introduce any error. Moreover, our values of relative intensities have also been checked by the results of the total-absorption gamma spectra and are, therefore, believed to be more reliable.

The nucleus of Sb^{125} with only one proton outside a closed shell, may be considered to have a nondeformed shape. The low-lying excited state in Sb^{125} may, therefore, be considered to be due to a coupling between the single particle orbitals of the odd proton and the harmonic vibrations of the even-even core. Such an interpretation has been suggested by Silverberg[9] and all the excited states observed can be qualitatively explained by considering the coupling of the $g\,\frac{7}{2}$ and $d\,\frac{5}{2}$ proton orbitals to the 2^+ one-phonon excitation of the core. However, even though the spin assignment of the levels is not inconsistent with such an interpretation, it is found that the center of gravity rule[10] is not satisfied. The center of gravity of the levels due to the coupling between the $\frac{7}{2}^+$ orbital and 2^+ one-phonon state should be at 1130 keV, the first excited state of Sn^{124}.[11] Similarly, the center of gravity of the levels due to the coupling between the $\frac{5}{2}^+$ orbital and 2^+ state should be at 1455 keV. Making a plausible assignment of the observed levels to the $g\,\frac{7}{2}$ and $d\,\frac{5}{2}$ core multiplets, the centers of gravity are found to be 1409 and 1638 keV, respectively. Since these are considerably different from the expected values, it seems that some of the high-energy excited states cannot arise due to this type of excitation. The nature of these excited states can be definitely established only when unambiguous spin and parity assignments to the levels and M1-E2 mixing ratios for the various gamma transitions are available from angular correlation and conversion coefficient measurements.

ACKNOWLEDGMENTS

The authors wish to thank Professor B. V. Thosar for his interest in the work, P. N. Tandon for help in the measurements, A. T. Rane for chemical separations, and R. R. Hosangdi for wiring the electronic circuits used in this work. It is a pleasure to acknowledge the cooperation of the Reactor Superintendent, G. V. Nadkarny and the staff of the Apsara Reactor in carrying out the irradiations.

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