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^{129}Sn and ^{129}Sb beta decays

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Samples of ^{129}Sn and ^{129}Sb were obtained by on-line mass-separation techniques applied to ^{235}U thermal-fission products. Half-lives of (6.9 ± 0.1) and (2.5 ± 0.1) min have been measured for the ^{129}Sn beta decays. Decay schemes are proposed based on gamma-ray energies and intensities and gamma-gamma coincidence results. A new half-life of (17.7 ± 0.1) min, besides the well known 4.4 h one, was observed in the ^{129}Sb decay. A level scheme fed by this decay is proposed taking into account our results and previously reported nuclear reactions data. The ^{129}Sb structure is compared with a particle-core coupling calculation.

[RADIOACTIVITY ^{129}Sn and ^{129}Sb decays [from ^{235}U(n_{th},f)]; on-line measured E_γ, I_γ, γ-γ coincidences, $T_{1/2}$, Ge(Li) detectors; ^{129}Sb and ^{129}Te deduced levels. Mass-separated ^{129}Sn and ^{129}Sb activities.]

I. INTRODUCTION

Several efforts have been made in recent years to improve the knowledge of the structure of the Sn, Sb, and Te isotopes in the neighborhood of ^{132}Sn. In the 129 mass chain the ^{129}In decay was studied by De Geer and Holm[1] and the half-lives of the two short lived ^{129}Sn isomers have been reported by Fowler *et al.*[2] and Grapengiesser *et al.*[3] The long lived ^{129}Sb (4.4 h) beta decay has been studied by Ohya *et al.*,[4] producing the activity through the ^{130}Te$(\gamma,p)^{129}$Sb reaction. Also nuclear reaction studies established several ^{129}Te excited levels,[5] though only a few of them with $J\pi$ assignments. Radiochemical experiments for independent yield and genetic determinations were also reported by Fowler and Whal,[6] isolating ^{129}Sn with a fast chemical separation procedure, and ^{129}Sb with a slow one after waiting one hour. A 3 μs isomeric state and four gamma rays have been reported by Heyde *et al.*[7] together with theoretical calculations on ^{129}Sb levels. More particle-core coupling calculations have been done by Sau and Heyde.[8]

Here we report results of measurements performed on the several ^{129}Sn and ^{129}Sb beta decays. These isotopes were obtained as ^{235}U thermal fission products, using an on-line electromagnetic isotope separator facility. Half-lives and partial decay schemes for the ^{129}Sn (2.4 min) and ^{129}Sn (6.9 min) isotopes are established, leading to a level scheme for ^{129}Sb for which the lowest lying levels are interpreted in terms of the coupling of single proton states to the collective ones based on the neutron holes.

In the ^{129}Sb decay a new half-life of 17.7 min has been found, besides the 4.4 h half-life reported previously. Its assignment to ^{129}Sb is supported by the results of growth-decay experiments on ^{129}Sb (17.7 min) and ^{129}Te (69 min) activities. A partial decay scheme is also proposed, for which most of the levels are not seen in the $\frac{7}{2}^+$ ^{129}Sb g.s. decay, but some

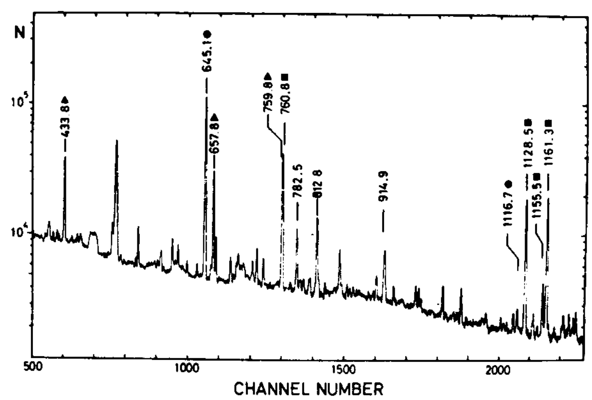

FIG. 1. A gamma-ray spectrum of the $A=129$ isobars. The recording was made during one hour. The dots correspond to the decay of ^{129}Sn (2.4 min), the black squares to the decay of ^{129}Sn (6.9 min), the triangles to the decay of ^{129}Sb (17.7 min), and the others, to the 4.4 h ^{129}Sb decay.

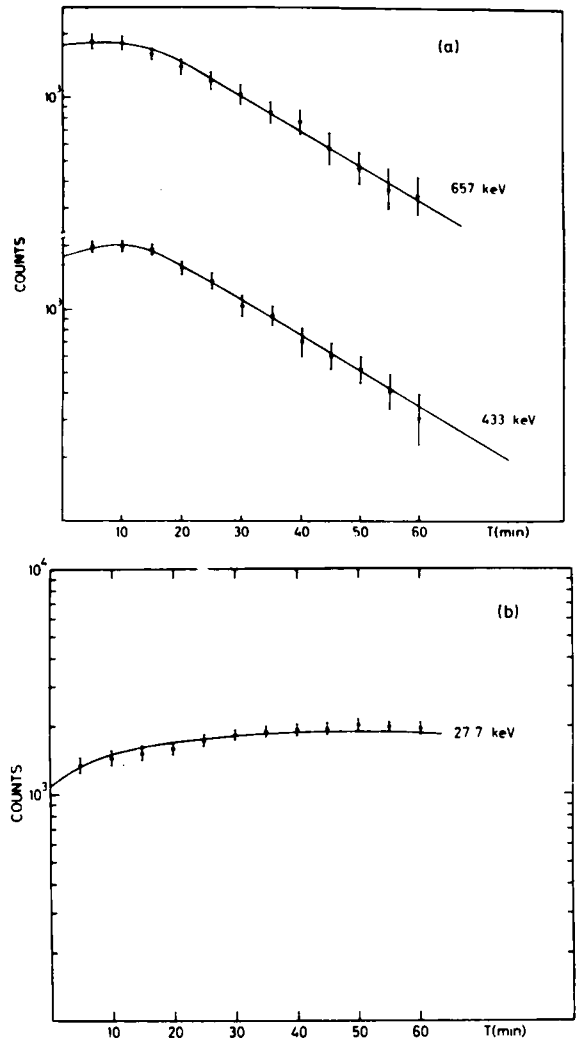

FIG. 2. (a) Growth-decay curves of the most important gamma transitions in the ^{129}Sb decay (17.7 min). (b) Growth-decay curve of the 27.7 keV gamma transition of ^{129}I, fed in the ^{129}Te beta decay.

of them are supported by nuclear reaction results. This new half-life has been missed up to now, probably, in the case of De Geer and Holm,[1] because they looked only at the short lived In activities, but the most intense 17.7 min gamma rays were actually present in their gamma spectra. In the case of Fowler and Whal (Ref. 6) the reason is probably that the Sb separation started after waiting for one hour, and in that of Ref. 4, because the ^{129}Sb activity was produced by a different method.

II. EXPERIMENTAL TECHNIQUES

The mass-129 activity was obtained from the thermal fission of ^{235}U in the IALE facility described elsewhere.[9] Basically a hot (1.700 °C) graphite-uranium carbide mixture is held by a graphite cloth inside the ion source of an electromagnetic isotope separator. The fission products produced by bombardment with thermal neutrons diffuse from the target and are immediately ionized, mass analyzed, and collected on a moving tape collector where the Ge(Li) detectors are placed allowing direct on line measurements. No contaminations from other masses were observed.

A 95 cm^3 Ge(Li) detector was used to measure singles gamma-ray spectra. This one, together with a 45 cm^3 Ge(Li) detector, was employed for coincidence measurements. The energy resolution of these detectors was 1.85 and 2.5 keV, respectively, at 1.33 MeV.

The collector assembly was operated with different time schedules to vary the activity ratios according to their half-lives and parental relationships, obtaining a positive assignment for the detected radiations. Typically, spectra were taken with the following time schedules:

(a) continuous collection and counting, moving the tape every two minutes;

(b) fifteen min collection and counting, 5 min waiting (no collection), 15 min counting (no collection), moving the tape at the end of each cycle;

(c) one hour collection and counting, 15 min waiting (no collection), one hour counting (no collection), and moving the tape at the end of the cycle.

Energy calibrations were made using the lines of the ^{57}Co, ^{60}Co, ^{88}Y, and ^{203}Hg standards and the gamma ray from the $H(n,\gamma)D$ reaction. Efficiency calibrations over the range 0.13–3.3 MeV were performed by collecting mass-138 activity[10] on line, with the same geometry as the one used for the mass-129 measurements. The low energy region was calibrated using ^{57}Co and ^{241}Am standard sources. Ge(Li) detectors were used also to look at characteristic x-ray spectra.

Spectra were analyzed by computer methods using the ANPIK[11] program and the energy calibration curve was fitted with the code CALIB.[11] Bidimensional coincidence spectra [Ge(Li)-Ge(Li)] were recorded (resolution time, approximately 100 ns) and analyzed by scanning the resulting tapes on a computer.

Half-lives as well as parental properties were determined by means of Ge(Li) gamma spectra scaling with different time intervals for the activity accumulations.

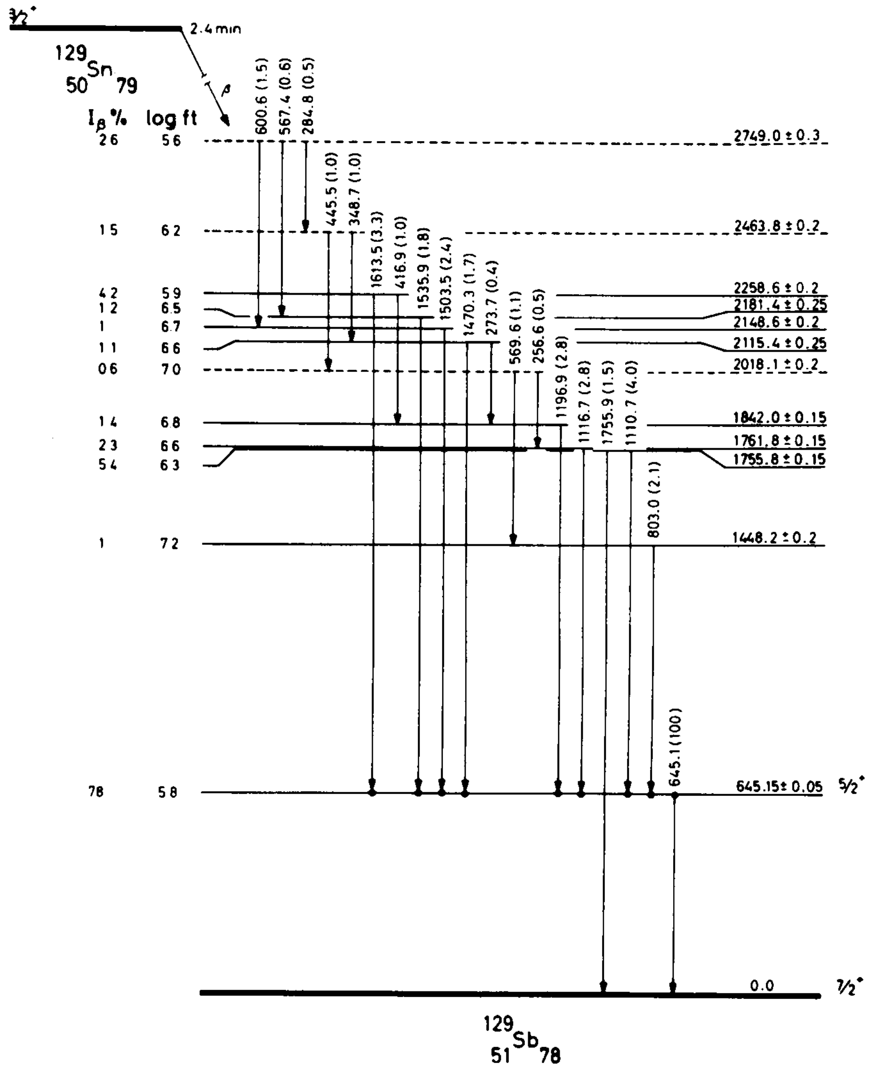

FIG. 3. Partial decay scheme for ^{129}Sn (2.4 min).

III. EXPERIMENTAL RESULTS

Figure 1 shows a typical singles on-line spectrum where the ^{129}Sn activity is enhanced with respect to the ^{129}Sb by an appropriate sequence for the moving tape collection time. An example of the complexity of these spectra is the 760 keV gamma line composed of the 760.80 keV (6.9 min), 759.83 keV (17.7 min), and 761.0 keV (4.4 h, very weak in our case) lines.

Three half-lives were observed besides the well known 4.4 h ($\frac{7}{2}^+$, g.s. ^{129}Sb) and 69 min ($\frac{3}{2}^+$, g.s. ^{129}Te), with values of 2.4 ± 0.1, 6.9 ± 0.1, and 17.7 ± 0.1 min.

The half-lives of 2.4 and 6.9 min were measured recording 16 successive gamma spectra (one minute each) after 15 min of activity accumulation and repeating the cycle several times. The values were obtained from the decay rate of the 645.13 keV line (2.4 min) and as weighted averages of the ones of 306.96, 782.48, 1128.44, and 1163.31 keV lines (6.9 min).

The same procedure, but scaling every 5 min, was used for the 17.7 min half-life measurement. The 433.76 and 657.78 keV gamma lines were taken into account in these cases.

The Sb x rays show only the 6.9 min half-life with no contribution larger than 3% from the 2.4 or 17.7 min half-lives. The x-ray spectrum taken with all the activities saturated (more than one hour accumulation) shows only the Sb lines and the Sn and Te lines were below 1% of the Sb ones. The 2.4 and 6.9 min activities have been assigned to ^{129}Sn and ^{129}Sn^m, respectively, in view of the decay rates

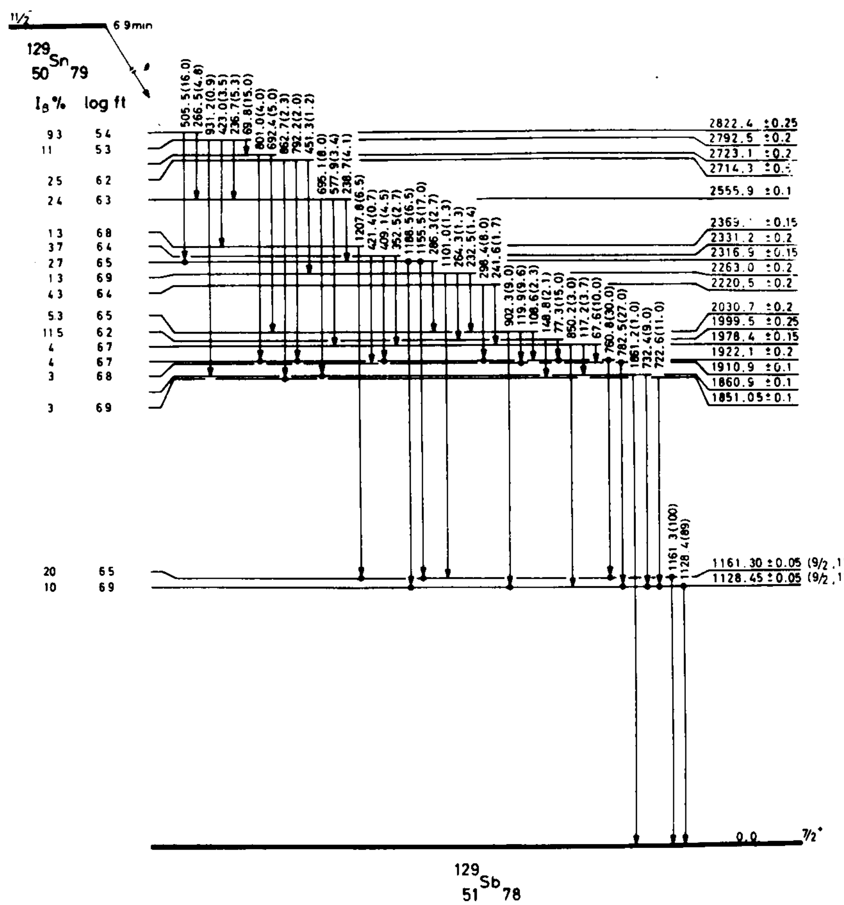

FIG. 4. Partial decay scheme for ^{129}Sn (6.9 min).

of the characteristic x rays and the most intense gamma rays previously reported in Ref. 2, in good agreement with De Geer and Holm (Ref. 1).

The 17.7 min half-life was assigned to ^{129}Sb taking into account the growth-decay curves shown in Fig. 2. The computer fitting of these curves, performed with all the half-lives and the initial activities as free parameters, yields values of 7 ± 1 and 18.7 ± 1 min for the 657 and 433 keV lines, and 18 ± 2 and 70 ± 5 min for the 27.7 keV line independently of the initial activities (collection times). It was clear that the 6.9 min activity (^{129}Sn) feeds the 17.7 min one, and the 17.7 min decay then feeds the 69 min ^{129}Te activity. The 2.4 min activity contributions were smaller than 3% of the initial growth portion of the curve in Fig. 2(a). Also, the most intense gamma ray showing the half-life of 17.7 min (759.83 keV) corresponds to a level in ^{129}Te well established by nuclear reactions. The results on the different decays of the $A=129$ mass chain are summarized in Tables I–III. For each decay a table is presented which lists the observed gamma-ray energies and the relative intensities, along with the errors in these quantities. Coincidence results are presented in Tables IV–VI.

No intense gamma rays were observed above 2 MeV within the experimental sensitivity, probably due to the high energy gamma background from (n,γ) reactions in shieldings.

IV. LEVEL SCHEMES

A. Decay schemes of ^{129}Sn^m and ^{129}Sn

The decay schemes proposed in this work for ^{129}Sn and ^{129}Sn^m are shown in Figs. 3 and 4. They have been built using the experimental results mentioned above.

For the 2.4 min ^{129}Sn decay only the most intense transitions have been placed in the level scheme within a frame of 12 excited levels that holds 70% of the gamma intensity. The first excited state of the odd Sb isotopes shows a very regular behavior that allows us to assign the 645 keV gamma line to

TABLE I. Gamma ray from ^{129}Sn (2.4 min) decay.

Energy (keV)	Error (keV)	Relative intensity	Error	Energy (keV)	Error (keV)	Relative intensity	Error
66.4	0.3	5.0	1.0	598.2	0.2	1.1	0.3
80.5	0.1	6.6	0.9	600.6	0.2	1.5	0.3
82.2	0.2	2.3	0.5	618.6	0.2	1.5	0.4
139.8	0.1	2.3	0.2	645.13	0.08	100.0	0.0
182.2	0.1	0.7	0.1	803.0	0.2	2.1	0.6
190.2	0.2	0.5	0.1	858.2	0.2	1.7	0.5
192.6	0.2	0.5	0.1	867.7	0.2	1.2	0.4
198.1	0.1	2.2	0.2	897.7	0.4	0.8	0.3
202.9	0.2	0.9	0.1	913.2	0.2	5.0	1.0
256.6	0.2	0.5	0.1	1110.7	0.2	4.0	1.0
258.3	0.2	0.9	0.2	1116.7	0.1	2.8	0.7
262.6	1.00	0.0	0.0	1196.9	0.2	2.8	0.8
273.7	0.2	0.4	0.1	1203.7	0.2	2.5	0.7
284.8	0.3	0.5	0.1	1252.0	0.1	1.9	0.5
296.0	0.1	2.1	0.3	1406.6	0.3	1.2	0.4
336.0	0.1	1.7	0.2	1410.7	0.3	1.1	0.4
339.7	0.2	0.9	0.2	1470.3	0.2	1.7	0.6
348.7	0.2	1.0	0.2	1503.5	0.2	2.4	0.7
368.3	0.2	0.5	0.1	1510.0	0.3	1.0	0.4
372.3	0.3	0.6	0.2	1535.9	0.2	1.8	0.6
374.1	0.4	0.4	0.2	1613.5	0.2	3.3	0.9
385.9	0.3	0.7	0.2	1725.6	0.2	2.8	0.8
416.9	0.2	1.0	0.3	1755.9	0.3	1.5	0.5
445.5	0.2	1.0	0.2	1779.1	0.3	2.5	0.8
455.2	0.5	0.4	0.2	1831.8	0.3	1.8	0.6
541.0	0.3	0.8	0.3	1865.0	0.3	1.3	0.5
567.4	0.4	0.6	0.2	1915.2	0.3	1.5	0.5
569.6	0.2	1.1	0.3	1942.6	0.3	2.1	0.7
				1951.0	0.4	1.2	0.5

the deexcitation of the first excited level of ^{129}Sb. Based on it, the rest of the level scheme was built taking into account the gamma-gamma coincidence results, energy sums, and intensity balances. Nine of these levels were confirmed by gamma-gamma coincidences, and the other three levels had good energy agreement for at least three gamma rays.

In the level scheme deduced for the 6.9 min ^{129}Sn decay, 41 transitions have been placed connecting 19 excited levels. Sixteen of these levels were confirmed by the results of the gamma-gamma coin-

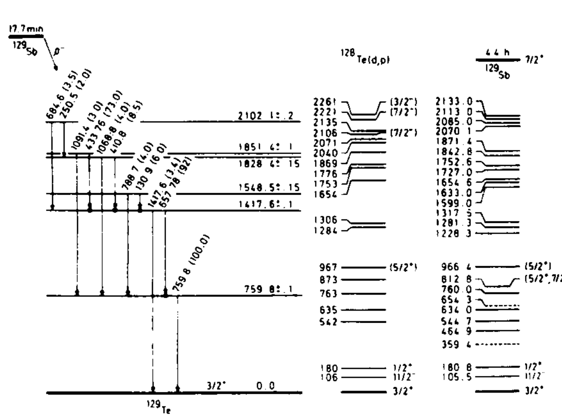

FIG. 5. Partial decay scheme for ^{129}Sb (17.7 min) and comparison with the previously known ^{129}Te levels.

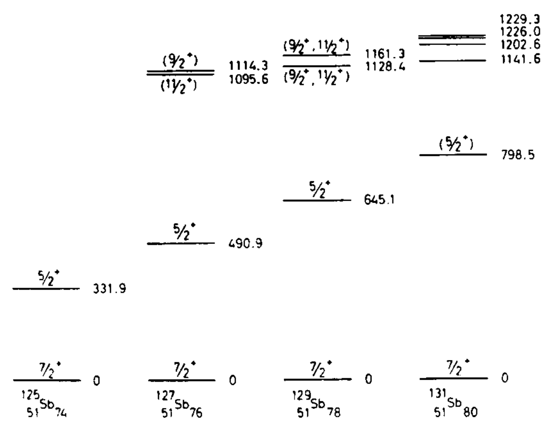

FIG. 6. Systematics for some levels of odd antimony isotopes.

TABLE II. Gamma ray from ^{129}Sn (6.9 min) decay.

Energy (keV)	Error (keV)	Relative intensity	Error	Energy (keV)	Error (keV)	Relative intensity	Error
50.2	0.1	10.0	5.0	451.3	0.4	1.2	0.4
67.6	0.2	10.0	3.0	505.5	0.2	16.0	3.0
69.8	0.1	15.0	5.0	573.9	0.2	3.2	0.8
77.3	0.1	15.0	9.0	577.9	0.2	3.4	0.9
97.5	0.2	1.2	0.4	579.4	0.2	6.0	1.0
103.7	0.3	0.8	0.3	604.9	0.1	9.0	2.0
108.6	0.2	2.3	0.7	692.4	0.2	5.0	1.0
109.6	0.4	1.5	0.6	695.1	0.1	8.0	2.0
111.5	0.1	4.8	0.6	716.2	0.2	6.0	2.0
117.2	0.1	3.7	0.9	722.6	0.1	11.0	3.0
119.9	0.05	9.6	0.9	732.4	0.1	9.0	2.0
148.8	0.1	2.1	0.3	760.8	0.2	30.0	4.0
156.1	0.2	1.6	0.3	780.5	0.7	1.0	0.5
159.3	0.3	0.8	0.3	782.48	0.08	27.0	5.0
206.4	0.2	1.3	0.3	792.2	0.5	2.0	1.0
219.3	0.1	10.3	0.9	801.0	0.2	4.0	1.0
225.6	0.1	2.8	0.4	815.6	0.2	2.7	0.7
232.5	0.2	1.4	0.3	850.2	0.2	3.0	1.0
236.7	0.1	5.3	0.5	862.7	0.2	2.3	0.8
238.7	0.1	4.1	0.4	902.3	0.1	9.0	2.0
241.6	0.1	1.7	0.3	928.4	0.2	5.1	1.5
264.3	0.6	1.3	0.9	931.2	0.7	0.9	0.6
266.5	0.2	4.8	0.7	962.0	0.1	6.0	1.5
286.3	0.2	2.7	0.4	970.1	0.2	3.0	1.0
298.4	0.1	8.0	1.0	1002.9	0.1	9.0	2.0
306.96	0.08	27.0	3.0	1101.0	0.4	1.3	0.5
311.3	0.1	5.6	0.7	1128.44	0.08	89.0	10.0
315.1	0.2	2.1	0.5	1141.6	0.4	3.5	1.5
320.7	0.2	3.0	1.0	1155.5	0.1	17.0	3.0
321.7	0.1	2.2	0.4	1161.31	0.08	100.0	2.0
352.5	0.2	2.7	0.7	1174.4	0.3	2.0	0.8
364.5	0.1	4.4	0.8	1188.5	0.2	6.5	2.2
385.9	0.3	1.5	0.5	1207.8	0.1	6.5	2.0
409.1	0.2	4.5	0.9	1349.7	0.2	3.0	1.0
421.4	0.6	0.7	0.3	1435.9	0.3	2.5	1.0
423.0	0.1	3.5	0.3	1597.4	0.3	3.0	1.0
425.9	0.2	2.0	0.5	1720.9	0.3	3.0	1.0
435.4	0.2	2.2	0.6	18.61.2	1.0	1.0	0.5

cidence experiments. The remaining three levels are supported by energy sum agreements involving at least four gamma rays for each level. De Geer and Holm[1] suggest that the two lowest states of ^{129}Sn have spin and parity $\frac{11}{2}^-$ (6.9 min) and $\frac{3}{2}^+$ (2.4 min). These values are theoretically expected on a shell model basis: a neutron hole in the $1h_{11/2}$ and in the $2d_{3/2}$ shells, and agree with the systematic behavior of odd Sn isotopes. As we expect the $J\pi$ value for the ^{129}Sb ground state to be $\frac{7}{2}^+$ (see the next section), the beta decay from the $\frac{11}{2}^-$ (6.4 min) level in ^{129}Sn to this g.s. would be of the unique first-forbidden type, and therefore the beta intensity of this decay should be less than 0.1%, if we accept the logft value provided by the empirical rules of Raman and Gove.[12] In the case of the beta decay from the 2.4 min level in ^{129}Sn, the transition would be of the second forbidden type, and thus its intensity would be still lower. We are therefore justified in assuming zero intensity for the ^{129}Sb g.s. beta feeding for the purpose of calculating the logft values of the beta branches to the excited levels in this nucleus, using gamma intensity balances to calculate the respective beta feedings. For some levels, $J\pi$ values are suggested which also take into account the gamma deexcitations.

TABLE III. Gamma ray from ^{129}Sb^m (17.7 min) decay.

Energy (keV)	Error (keV)	Relative intensity	Error
39.0	0.2	6.0	2.0
61.1	0.8	3.0	1.0
63.6	0.9	10.0	3.0
130.9	0.1	6.0	2.0
146.0	0.2	1.8	0.5
186.0	0.4	1.7	0.5
250.5	0.2	2.0	0.5
281.1	0.4	1.0	0.3
346.9	0.3	2.0	0.5
410.8	0.1	8.5	2.0
433.76	0.08	73.0	8.0
435.6	0.3	1.8	0.5
438.0	0.2	1.8	0.5
443.0	0.4	1.4	0.5
453.5	0.2	4.0	1.2
583.3	0.4	1.5	0.5
657.78	0.08	92.0	8.0
684.6	0.2	3.5	1.0
759.8	0.1	100.0	0.9
788.7	0.2	4.0	1.5
793.5	0.3	5.0	1.5
825.4	0.3	8.5	3.0
1063.2	0.4	2.0	1.0
1068.8	0.2	4.0	1.5
1091.4	0.2	3.0	1.0
1225.5	0.2	4.0	1.0
1327.1	0.3	2.8	1.0
1417.6	0.3	3.4	1.2
1843.1	0.5	1.8	0.5

None of the gamma transitions reported by Heyde *et al.*[7] have been seen in the ^{129}Sn ($\frac{11}{2}^-$, 6.9 min) decay that should feed the 3 μs, $\frac{13}{2}^-$ proposed isomer in ^{129}Sb. The most probable explanation may be a wrong Z assignment for this isomer, as is pointed out by De Geer and Holm.[1]

Several intense gamma rays as well as two pairs of coincidences are not placed in our level scheme because of the lack of clear relationships with other gamma rays. Looking at the ^{127}Sb and ^{131}Sb levels, an isomeric one is expected at approximately 1.8 MeV and its existence could be the reason for the break in the level scheme. Anyhow, the low lying levels are well established from both decays and allow a reasonable comparison with the theory, as stated in the next section. This level scheme was built on the $\frac{7}{2}^+$, g.s. of ^{129}Sb. Our experimental results do not allow us to establish the position of the 17.7 min isomeric level, which could also be responsible for breaks in the level scheme.

B. Decay scheme of ^{129}Sb^m

The results for the ^{129}Sb^m decay with the 17.7 min half-life allow us to build the decay scheme shown in Fig. 5. The first excited level, that where the most intense gamma transition originates, is also found in the ^{128}Te(d,p)^{129}Te reaction (Ref. 5). This implies a disagreement with Ref. 4. Clearly their 760 keV level is not the same level as our first excited level in view of the absence of the 654.3-, 295.5-, and 359.4-keV gamma rays in our 17.7 min decay spectra, and the absence of the direct g.s. transition in the scheme of Ref. 4. The alternative of a different placing of the 654.3 keV gamma ray has also been discussed in Ref. 4, and seems more likely.

Seven levels are proposed, holding 11 gamma rays with ~85% of the gamma intensity. Two of these levels agree with the ones observed in the ^{128}Te(d,p)^{129}Te reaction. In general, the levels fed in the 17.7 min beta decay are not populated in the 4.4 h one.

TABLE IV. Gamma-gamma coincidences in the ^{129}Sn (2.4 min) decay.

Gamma-ray energy (keV)	Gamma ray in coincidence (keV)	Level scheme position E_f	E_i
645.13	803.0,1110.7,1116.7,1196.9, 1470.3,1503.5,1535.9	0	645.15
803.0	645.13	645.15	1488.2
1110.7	645.13	645.15	1755.8
1116.7	645.13	645.15	1761.8
1196.9	645.13	645.15	1842.0
1470.3	645.13	645.15	2115.4
1503.5	645.13	645.15	2148.6
1535.9	645.13	645.15	2181.4
1613.5	645.13	645.15	2258.6

TABLE V. Gamma-gamma coincidence in the ^{129}Sn (609 min) decay.

Gamma-ray energy (keV)	Gamma ray in coincidence (keV)	Level scheme position E_f	E_i
77.3	760.8,1161.31	1922.1	1999.5
219.3	716.2		
298.4	760.8,1161.31	1922.1	2220.5
306.96	928.4		
505.5	1128.44,1155.5,1161.31,1188.5	2316.9	2822.4
579.4	1161.31		
716.2	219.3		
722.6	1128.44	1128.45	1851.05
732.4	1128.44	1128.45	1860.9
760.8	298.4,409.1,801.0,1161.31	1161.30	1922.1
782.48	119.9,1128.44	1128.45	1910.9
792.2	760.8,1161.31	1922.1	2714.3
801.0	760.8,1161.31	1922.1	2733.1
902.3	1128.44	1128.45	2030.7
928.4	306.96		
1128.44	505.5,722.6,732.4, 782.48,902.3,1188.5	0	1128.45
1155.5	505.5,1161.31	1161.30	2316.9
1161.31	298.4,505.5,760.8, 792.2,801.0,1155.5,1207.8	0	1161.30
1188.5	505.5,1128.44	1128.45	2316.9
1207.8	1161.31	1161.30	2369.1

V. DISCUSSION

Until now there was very scarce information available concerning the levels of ^{129}Sb. The ground state is very likely $\frac{7}{2}^+$, as is the case for the nearby odd Sb isotopes. This is consistent with the idea of the proton above $Z=50$ lying in the $g_{7/2}$ shell model state.

Figure 6 shows the systematic behavior of the first excited levels in this region for the odd Sb isotopes. The remarkable regular increase of the energy spacing between the $\frac{5}{2}^+$ and the $\frac{7}{2}^+$ ground state is clearly seen. The 1128 and 1161 keV levels are probably the homologous of the two levels at 1095 and 1141 keV found in ^{127}Sb (Ref. 13) and of the multiplet found in ^{131}Sb (Ref. 14).

The ^{129}Sb energy levels can be interpreted as the ones generated by a proton interacting with a ^{128}Sn core. The latter can be studied as four neutron holes in the doubly magic ^{132}Sn core, and its ground state described, in a very good approximation, as a two 0^+ boson state, where each boson is built as a coherent two hole state. In the same way the first 2^+ excited state will be the one with one boson carrying angular momentum two. The boson energies were worked out from a Tamn Dancoff approximation (TDA) treatment of a multipole pairing Hamiltonian[15] and is obtained from the dispersion relation

$$\frac{1}{4\pi G_\lambda}=\frac{1}{2}\sum_{j_1 j_2}\frac{|\langle j_1||r^\lambda Y_\lambda||j_2\rangle|^2}{\epsilon_{j_1}+\epsilon_{j_2}-\omega_\lambda},$$

TABLE VI. Gamma-gamma coincidences in the ^{129}Sb^m (17.7 min) decay.

Gamma-ray energy (keV)	Gamma ray in coincidence (keV)	Level scheme position E_f	E_i
130.9	657.78,759.8	1417.6	1548.5
410.8	657.78,759.8	1417.6	1828.4
433.76	657.78,759.8,1417.6	1417.6	1851.4
657.78	410.8,433.76,759.8	759.8	1417.6
759.8	410.8,433.76,657.78	0	759.8
1417.6	410.8,433.76	0	1417.6

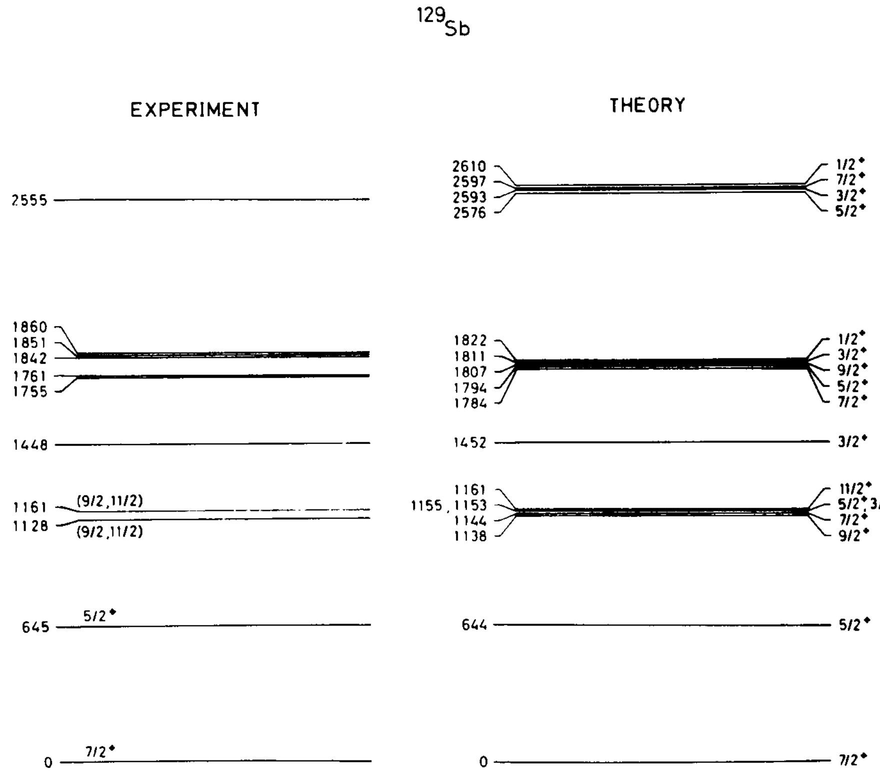

FIG. 7. Comparison of experimental results (tentative $J\pi$ assignments) with particle-core coupling calculations (see text).

where ϵ_j is the single particle energy and ω_λ is the boson energy. The coupling constant G_λ was fixed by fitting the experimental binding energy of the lowest state with spin λ in the two boson nucleus ^{128}Sn.

The theoretical ^{129}Sb level scheme was built as a proton coupled to the ^{128}Sn core assuming a quadrupole interaction between the proton and the bosons in the same way as was done in the description of ^{131}Sb (Ref. 14). The interaction Hamiltonian is

$$H_Q=-\frac{\chi}{2}\sum_{\mu}(Q_\mu^+)_\pi(Q_\mu)_\nu+(Q_\mu^+)_\nu(Q_\mu)_\pi ,$$

where $(Q_\mu)_\pi$ $[(Q_\mu)_\nu]$ are the proton (neutron) quadrupole operators

$$Q_\mu=\frac{1}{\sqrt{5}}\sum_{j_1j_2}\langle j_1||r^\lambda Y_\lambda||j_2\rangle[C_1^+C_2]_\mu{}^2 .$$

The strength of the interaction, χ, has been obtained in Ref. 12 from a fit of the experimental ^{131}Sb data within the framework of Nuclear Field Theory (NFT).[16] The theoretical predictions and the experimental data are compared in Fig. 7.

Recently, shell-model particle-core coupling calculations have been carried out by Sau and Heyde[8] to determine the strengths of the multipole-multipole force, but their treatment is different from our NFT calculation.

The ^{129}Sb isomeric level with a 17.7 min half-life feeds a set of levels completely different from those already known; they are probably related to single neutron excitations.

The discovery of such a long lived isomeric state in this already well explored region suggests a revision of independent yield calculations and electron spectra with precise beta energy determinations.

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