^{129m}Sn - Comments on evaluation of the decay data

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This evaluation was performed considering the literature available by end of January 2024.

1. Nuclear data

The latest recommended value from the Atomic Mass Evaluation (AME) 2020 [2021WA16] was adopted: Q_β = 4039 (27) keV. The energy of the metastable state is 35.2 (2) keV deduced from the difference of level energies measured in [2021GA10].

Only [1982HU09] and [1987ST23, 1987STZO] have proposed a decay scheme, both based on γ-γ coincidences. However, many γ-rays were seen in [1987ST23, 1987STZO] but not in [1982HU09]. More than half of the common γ-rays do not have consistent intensities. In addition, both studies have internal inconsistencies in their proposed decay schemes.

In the present evaluation, the decay scheme was mainly based on the results from [1987STZO] because of the additional measurement of conversion electrons, and because the inventory of the γ transitions seems more reliable. This decay scheme can only be considered as tentative.

1.1. Half-lives

The following half-lives were studied in this evaluation. Two methods were employed to study the A = 129 isotopes:

i) Irradiation of a ^{235}U target and subsequent chemical purification. Sample activity was then followed by either β counters or γ detectors.

ii) Online isotopic separation of fission products, implanted on tapes. Measurements are then performed in coincidence with γ detectors.

^{129}Sn – Ground state

Table 1 – Measured half-life values of the ground state of ^{129}Sn.

References	$T_{1/2}$ (min)	Comments
1962HA16	57.6 (31)	Not used, out of range
1967BI15	2.5	Not used, no uncertainty
1972IZ01	2.52 (12)	
1974FO06	2.50 (27)	Recalculated, but no systematic uncertainty
1974GR29	2.25 (5)	Recalculated, but no systematic uncertainty
1980DE35	2.16 (4)	No detail, no systematic uncertainty
1982HU09	2.4 (1)	
1987STZO	2.5	Not used, no uncertainty
Recommended	**2.23 (5)**	Weighted mean, external uncertainty

The measured half-lives available in the literature are given in Table 1. The value from [1962HA16] differs from the others by more than an order of magnitude; it was thus rejected.

Values reported without uncertainty were also not considered. The values from [1974FO06, 1974GR29] were recalculated based on the different measurements listed in the publications considering their arithmetical mean. Uncertainties are calculated from the deviation of the single measurements to the mean, combined with any given uncertainty on the individual values. It should be noted that only statistical uncertainty was given in the publications. The resulting dataset is consistent, with χ^2 = 3.23 and χ^2-crit. = 3.32. A weighted average with external uncertainty was considered to account for underestimation of the measurement uncertainties. The recommended half-life is **$T_{1/2}$ = 2.23 (5) min**.

^{129m}Sn – 35 keV

Table 2 – Measured half-life values of the 35-keV level of ^{129}Sn.

References	$T_{1/2}$ (min)	Comments
1962DR01	6.2 (12)	Na(I)Tl
1962HA16	8.8 (6)	Beta counter, not used
1967BI15	7.5 (1)	Beta counter, not used
1974FO06	7.3 (2)	Ge(Li)
1974GR29	8.9 (6)	Beta counter, not used
1980DE35	6.7 (4)	Ge(Li)
1982HU09	6.9 (1)	Ge(Li)
Recommended	**6.96 (9)**	Weighted mean, internal uncertainty

The measured half-lives available in the literature are given in Table 2. The whole dataset is discrepant (χ^2-crit. = 2.8 and χ^2 = 5.9). In [1967BI15], it is suggested that contamination is always present after any radiochemical procedure in ^{129}Sn studies, concluding that only the lowest values should be considered. One can also observed that gamma measurements systematically are lower. The largest consistent dataset (χ^2-crit. = 1.4 and χ^2 = 3.8) naturally excludes beta counter measurements. A weighted average with internal uncertainty was determined by the LWEIGHT program. The recommended half-life is **$T_{1/2}$ = 6.96 (9) min**.

^{129}Sb – Ground state

Table 3 – Measured half-life values of the ground state of ^{129}Sb.

References	$T_{1/2}$ (h)	Comments
1939AB02	4.2	Not used, no uncertainty
1953PA25	4.6 (1)	Outlier by Chauvenet's criterion
1962DR01	4.24 (10)	
1962UH01	4.34 (7)	
1966TA05	4.35 (6)	
1967HA27	4.31 (3)	
1974FO06	4.41 (1)	
Recommended	**4.362 (25)**	Weighted mean, external uncertainty

The measured half-lives available in the literature are given in Table 3. The value from [1939AB02] was not considered in absence of uncertainty. The value from [1953PA25] is an outlier by Chauvenet's criterion. The resulting dataset is consistent, with χ^2 = 2.1 and χ^2-crit. = 3.3. A weighted average with external uncertainty was determined by the LWEIGHT program. The recommended half-life is **$T_{1/2}$ = 4.362 (25) h**.

^{129m1}Sb – 1851 keV

Table 4 – Measured half-life values of the 1851-keV level of ^{129}Sb.

References	$T_{1/2}$ (min)	Comments
1982HU09	17.7 (1)	
1987STZO	17.1	
Recommended	**17.4 (3)**	Unweighted mean, covering uncertainty

Only two measurements, given in Table 4, are available in the literature and only [1982HU09] reports an uncertainty. The evaluator chose to consider their unweighted average and an uncertainty that covers both results. The recommended half-life is **$T_{1/2}$ = 17.4 (3) min**.

^{129m2}Sb – 1861 keV

Table 5 – Measured half-life values of the 1861-keV level of ^{129}Sb.

References	$T_{1/2}$ (µs)	Comments
1987STZO	> 2	Lower limit only
2003GE04	2.2 (2)	
Recommended	**2.2 (2)**	Adopted from 2003GE04

As shown in Table 5, only the measurement from [2003GE04] is available for this level, somehow confirmed by a lower limit from [1987STZO]. The recommended half-life $T_{1/2}$ = 2.2 (2) µs is adopted from [2003GE04].

1.2. Gamma-rays

The reported measurements of γ-rays in ^{129m}Sn decay are either illegible or very incomplete (no detail and often no uncertainty). Only two works, from [1982HU09] and [1987ST23, 1987STZO], reported energies and relative intensities that can be used in an evaluation. In both experiment, some A = 129 isotopes were produced from fission products separated online and implanted on a moving tape, and the emitted γ-rays were then measured in coincidence with germanium detectors. In [1987STZO], another setup allowed for conversion electron measurement with Si(Li) detectors.

Unfortunately, the γ-rays attributed to ^{129m}Sn decay in these two studies are not consistent. In addition, inconsistencies are also present in each study. Results from [1987STZO] were preferred in this evaluation, as the measurement is more complete and more detailed. Results from [1982HU09] were used to correct typos and inconsistencies in [1987STZO] when possible.

Level energies from γ-ray energies

The energy of the metastable state of ^{129}Sn is 35.2 (2) keV deduced from the difference of level energies measured in [2021GA10].

Emitted γ-ray energies of ^{129}Sb from [1987STZO] were first considered. For the γ-rays in common with [1982HU09], a simple mean of the two energies was determined. The corresponding uncertainty was determined as the maximum between *i*) the minimum of the two given uncertainties; and *ii*) half of the minimum distance between the values and their uncertainties. The list of the γ-ray energies is given in Table 6. Three γ-rays have energies that significantly differ. They were kept because of their close intensities.

These evaluated γ-ray energies were used to determine the level energies thanks to the GTOL program. For the 409-keV γ-ray, GTOL gives poor fit with the energy from [1987STZO] as input and recommends the level energy difference of 409.2 keV. The value from 1982HU09 was thus adopted. For the 445- and 1352-keV γ-ray, the values from [1987STZO] were adopted but doubling their uncertainty. The critical χ^2 of the dataset is 1.6 and the initial χ^2 is 3.8. After adjustment by least-square fitting, GTOL ends up with a χ^2 of 1.9, still slightly higher than the critical χ^2.

The adopted level energies are given in Table 7. The adopted energies of the γ transitions and emissions were then calculated consistently from the level energies.

Table 6 – Measured and evaluated γ-ray energies of ^{129}Sb which are common to [1982HU09] and [1987STZO].

E_γ (keV) 1982HU09	E_γ (keV) 1987STZO	E_γ (keV) Evaluated	E_γ (keV) 1982HU09	E_γ (keV) 1987STZO	E_γ (keV) Evaluated
50.20 (10)	50.13 (5)	50.17 (5)	505.50 (20)	505.50 (20)	505.50 (20)
67.60 (20)	67.47 (5)	67.54 (6)	573.90 (20)	574.7 (5)	574.30 (20)
69.80 (10)	69.67 (5)	69.74 (5)	577.90 (20)	578.80 (20)	578.35 (25)
77.30 (10)	77.34 (5)	77.32 (5)	695.10 (10)	695.43 (5)	695.26 (9)
108.60 (20)	108.81 (5)	108.70 (5)	716.20 (20)	716.40 (40)	716.30 (20)
111.50 (10)	111.78 (5)	111.64 (7)	722.60 (10)	722.69 (5)	722.64 (5)
117.20 (10)	117.40 (5)	117.30 (5)	732.40 (10)	732.48 (5)	732.44 (5)
119.90 (5)	119.92 (5)	119.91 (5)	760.80 (20)	761.00 (10)	760.90 (10)
156.10 (20)	156.18 (5)	156.14 (8)	782.48 (8)	782.59 (5)	782.54 (5)
159.30 (30)	159.40 (20)	159.35 (20)	850.20 (20)	851.3 (9)	850.75 (20)
219.30 (10)	219.48 (5)	219.39 (5)	902.30 (10)	902.39 (5)	902.34 (5)
236.70 (10)	236.96 (5)	236.83 (6)	962.00 (10)	961.80 (20)	961.90 (10)
286.30 (20)	285.98 (6)	286.14 (6)	1128.44 (8)	1128.60 (5)	1128.52 (5)
298.40 (10)	299.00 (10)	298.70 (20)	1141.60 (40)	1141.5 (8)	1141.6 (6)
306.96 (8)	307.00 (5)	306.98 (5)	1155.50 (10)	1155.72 (9)	1155.61 (9)
311.30 (10)	311.47 (5)	311.38 (5)	1161.31 (8)	1161.42 (5)	1161.36 (5)
320.70 (20)	320.90 (10)	320.80 (10)	1174.40 (30)	1174.42 (5)	1174.41 (16)
321.70 (10)	322.03 (8)	321.86 (8)	1188.50 (20)	1188.6 (5)	1188.55 (30)
385.90 (30)	386.00 (20)	385.95 (20)	1207.80 (10)	1207.70 (20)	1207.75 (10)
409.10 (20)	408.00 (20)	409.10 (20)	1349.70 (20)	1352.07 (5)	1352.07 (10)
423.00 (10)	422.30 (20)	422.65 (20)	1435.90 (30)	1436.10 (10)	1436.00 (10)
425.90 (20)	426.90 (20)	426.40 (30)	1597.40 (30)	1597.40 (20)	1597.40 (20)
435.40 (20)	445.20 (20)	445.20 (40)	1720.90 (30)	1720.60 (20)	1720.75 (20)
451.30 (40)	451.4 (5)	451.35 (40)			

Internal conversion and γ-ray intensities

No isomeric transition from the (11/2$^-$, 35 keV) level of ^{129}Sn to its (3/2$^+$) ground state has been observed and reported in the literature yet. Such a γ transition would be M4 with possible E5 admixture, with an upper limit of 0.002% [2014TI05]. Assuming pure M4, the BrIcc program [2008KI07] provides a total internal conversion coefficient α_T = 2.4(1) x 10^5. Therefore, one might expect a transition of very low intensity and highly converted, making any measurement of the low-energy electrons very difficult. In the present evaluation, no isomeric transition was included in the decay scheme of ^{129m}Sn.

Relative I_γ intensities of ^{129}Sb de-excitation were measured by [1982HU09, 1987STZO]. In addition, $I_{\gamma+ce}$ intensities were also reported by [1987STZO] for low-energy emissions up to 236.96 keV. The author assumed that conversion electron contribution to the γ transition is negligible above this energy, which was confirmed by the evaluator with BrIcc calculations. In the present evaluation, multipolarities, mixing ratios and internal conversion coefficients for these low-energy emissions were adjusted employing the BrIcc program [2008KI07]. Starting from the J^π assignments of [2014TI05], the aim was to retrieve the measured $I_{\gamma+ce}$ intensities from the I_γ intensities. The final levels for the 79.40- and 82.50-keV γ emissions were incorrectly assigned in [1987STZO]. Non-null mixing ratios for the 130.91-, 135.70- and 156.18-keV γ emissions are possible but with 100% relative uncertainty. For the 77.34- and 79.40-keV γ emissions, it was not possible to retrieve $I_{\gamma+ce}$ from the I_γ and I_γ was recalculated from $I_{\gamma+ce}$ and α_T. The same procedure was done for the 9.8-keV γ emission as $I_{\gamma+ce}$ was not measured but only deduced from decay scheme imbalance by [1987STZO]. Table 8 presents the results of this analysis, where the intensities were normalised in [1987STZO] such as I_γ(1128.6 keV) = 1000.

Table 7 – Adopted level energies of ^{129}Sb as determined by GTOL.

Level #	Energy (keV)	$T_{1/2}$	Level #	Energy (keV)
0	0	4.362 (25) h	27	2564.65 (10)
1	1128.560 (40)		28	2568.22 (8)
2	1161.350 (40)		29	2611.19 (8)
3	1851.22 (6)	17.40 (30) min	30	2664.98 (8)
4	1860.97 (5)	2.20 (20) μs	31	2678.25 (9)
5	1911.11 (5)		32	2697.33 (31)
6	1922.22 (5)		33	2722.28 (8)
7	1928.54 (5)		34	2726.12 (8)
8	1940.29 (7)		35	2766.80 (10)
9	1972.61 (5)		36	2796.76 (21)
10	1991.87 (5)		37	2822.95 (14)
11	2030.93 (5)		38	2863.99 (15)
12	2147.95 (6)		39	2881.91 (16)
13	2148.23 (7)		40	2884.23 (10)
14	2220.92 (21)		41	2948.17 (21)
15	2231.93 (11)		42	2960.50 (40)
16	2247.25 (7)		43	3013.80 (40)
17	2270.93 (8)		44	3031.81 (21)
18	2294.51 (8)		45	3069.92 (8)
19	2297.12 (10)		46	3096.93 (20)
20	2303.26 (7)		47	3130.7 (8)
21	2317.06 (6)		48	3148.03 (7)
22	2329.75 (21)		49	3163.97 (11)
23	2369.13 (8)		50	3208.67 (12)
24	2377.2 (6)		51	3274.02 (11)
25	2430.26 (7)		52	3280.62 (11)
26	2434.34 (7)			

Table 8 – Deduced multipolarities, mixing ratios and internal conversion coefficients of the low-energy γ emissions of ^{129}Sb from the relative intensities I_γ and $I_{\gamma+ce}$ measured in [1987STZO]. Intensities were normalised in [1987STZO] such as I_γ(1128.6 keV) = 1000.

E_γ (keV)	Relative I_γ	Relative $I_{\gamma+ce}$	E_{ini} (keV)	J^π_{ini}	E_{fin} (keV)	J^π_{fin}	Multipolarity	|δ|	α_T	$I_{\gamma+ce}$ OR I_γ
9.8		186 (5)	1860.97	15/2-	1851.22	19/2-	E2		3.66 (17) E+04	**0.00508 (27)**
39.04 (5)	0.92 (5)	11.4 (6)	2030.93	11/2-, 13/2-	1991.87	13/2-	M1+5.0%E2	0.230 (10)	11.46 (24)	11.5 (7)
44.04 (5)	19.3 (10)	207 (10)	1972.61	13/2-	1928.54	17/2-	M1+12.0%E2	0.370 (20)	9.70 (40)	207 (13)
50.13 (5)	32.80 (30)	178.0 (20)	1911.11	13/2-	1860.97	15/2-	M1		4.53 (7)	181.4 (28)
61.55 (5)	12.20 (40)	45.0 (10)	1972.61	13/2-	1911.11	13/2-	M1+2.8%E2	0.170 (20)	2.69 (6)	45.0 (16)
67.47 (5)	2.20 (20)	6.4 (6)	1928.54	17/2-	1860.97	15/2-	M1		1.910 (30)	6.4 (6)
69.67 (5)	34.1 (10)	94.0 (30)	1991.87	13/2-	1922.22	11/2-	M1		1.742 (25)	93.5 (29)
77.34 (5)	7.06 (5)	214 (5)	1928.54	17/2-	1851.22	19/2-	M1		1.290 (19)	**93.4 (23)**
79.40 (10)	0.70 (10)	6.0 (30)	1940.5	15/2-, 17/2-	1860.97	15/2-	M1		1.199 (18)	**2.7 (14)**
80.68 (5)	22.0 (30)	48 (7)	1991.87	13/2-	1911.11	13/2-	M1+1.9%E2	0.140 (30)	1.188 (22)	48 (7)
82.50 (20)	5.40 (10)	11.80 (20)	2329.9	13/2-	2247.25	13/2-, 15/2+	M1+5.4%E2	0.240 (10)	1.190 (21)	11.83 (25)
108.81 (5)	16.6 (5)	24.8 (7)	2030.93	11/2-, 13/2-	1922.22	11/2-	M1+1.0%E2	0.100 (30)	0.495 (9)	24.8 (8)
111.78 (5)	17.90 (20)	26.50 (30)	1972.61	13/2-	1860.97	15/2-	M1+4.2%E2	0.210 (20)	0.480 (9)	26.49 (34)
117.40 (5)	37.70 (30)	41.50 (30)	2148.43	9/2, 11/2, 13/2	2030.93	11/2-, 13/2-	E1		0.1200 (17)	42.22 (34)
119.92 (5)	56.2 (9)	77.0 (10)	2030.93	11/2-, 13/2-	1911.11	13/2-	M1		0.371 (6)	77.1 (13)
123.44 (5)	48.40 (30)	62.50 (40)	2270.93	15/2-	2147.95	15/2-	M1		0.342 (5)	64.95 (47)
130.91 (5)	4.00 (30)	5.20 (40)	1991.87	13/2-	1860.97	15/2-	M1		0.2900 (40)	5.16 (39)
135.70 (10)	2.20 (30)	2.80 (40)	2430.26	11/2-, 13/2+	2294.51	9/2- to 15/2+	M1		0.2630 (40)	2.78 (38)
145.3 (6)	13.70 (30)	16.80 (40)	2378.4	9/2, 11/2, 13/2	2231.93	9/2-, 11/2-, 13/2	M1+3.8%E2	0.20 (10)	0.226 (11)	16.80 (40)
156.18 (5)	10.50 (30)	12.4 (5)	2148.23	15/2-	1991.87	13/2-	M1		0.1780 (30)	12.37 (35)
159.40 (20)	9.40 (20)	11.20 (30)	2430.26	11/2-, 13/2+	2270.93	15/2-	E1+12.6%M2	0.380 (30)	0.191 (20)	11.20 (30)
175.36 (5)	9.10 (20)	10.40 (20)	2148.23	15/2-	1972.61	13/2-	M1+13.8%E2	0.40 (10)	0.143 (7)	10.40 (24)
219.48 (5)	73.0 (7)	80.3 (8)	2148.23	15/2-	1928.54	17/2-	M1+85.2%E2	2.4 (5)	0.1000 (30)	80.3 (8)
236.96 (5)	31.80 (30)	33.40 (30)	2148.23	15/2-	1911.11	13/2-	M1		0.0579 (9)	33.64 (32)

Imbalance of γ transitions

The relative γ intensities from [1987STZO], $I_{\gamma+ce}$ up to 236.96 keV and I_{γ} approximated as $I_{\gamma+ce}$ above, were gathered to establish level by level the ^{129}Sb de-excitation scheme. Any positive imbalance was assumed to come from a β feeding from ^{129m}Sn decay to the ^{129}Sb level. For the levels listed in Table 9, negative imbalance was found due to internal inconsistency of the [1987STZO] reported intensities. For the common γ emissions associated to these levels, the relative intensities from [1982HU09] were not found to be of any help to correct for these negative imbalances.

Choices were then made to balance the ^{129}Sb de-excitation scheme. For the 2270.93-keV level, the imbalance was absorbed in the intensity of the 279.6-keV γ transition, which uncertainty was doubled. For the 2147.95-keV level, the imbalance was distributed pro rata among the 156.18-, 175.36- and 236.96-keV γ transition, which uncertainties were doubled. For the 1928.54-keV level, the imbalance was absorbed in the intensity of the 67.47-keV γ transition, which uncertainty was multiply by 10. The rationale is that this transition starts from the same level as the 77.34-keV γ transition, both are of the same nature, but the latter was reported 33 times weaker in [1987STZO]. For the 1860.97-keV level, the imbalance was absorbed in the intensity of the 9.8-keV γ transition, which uncertainty doubled. Indeed, this transition was never observed but only deduced, and the reported intensities in [1987STZO] and [1987ST23] differ by about 40%.

After these corrections, negative imbalances are still present on the ground state and the 1851.22-keV level. The latter decays γ emission (intensity of a 722.65-keV γ-ray is reported in [1987]), but also by β transitions [2014TI05]. The ^{129}Sb de-excitation scheme was thus balanced assuming that the sum of the negative imbalances is 100%: 77.607% for the ground state and 22.393% for the 1851.22-keV level. The corresponding normalisation factor is 0.043162983.

The absolute γ transition probabilities P_{γ} were then deduced, as given in Table 10. The 722.65-keV γ transition and its related contribution to the 1128.56-keV γ transition were removed as they belong to the decay of ^{129m1}Sb (1851.22 keV, 17.4 min).

Table 9 – Negative imbalances in the ^{129}Sb de-excitation scheme before and after the corrections described in the text.

E_{level} (keV)	Before corrections			After corrections		
	I_{γ} in	I_{γ} out	Difference	I_{γ} in	I_{γ} out	Difference
0	1987.0 (14)		-1987.0 (14)	1987.0 (14)		-1987.0 (14)
1851.22	400 (7)	189.0 (10)	-211 (7)	519 (11)	0	-519 (11)
1860.97	222.1 (37)	220 (5)	-2 (6)	339 (7)	339 (10)	0
1928.54	337 (11)	220 (5)	-117 (12)	337 (11)	337 (8)	0
2147.95	147.1 (11)	136.5 (10)	-10.6 (15)	147.1 (11)	147.1 (15)	0
2270.93	73.6 (24)	66.5 (20)	-7.1 (32)	73.6 (24)	73.6 (40)	0

Table 10 – Absolute γ transition probabilities per 100 decays.

Transition	Energy (keV)	$P_{\gamma+ce}$ (%)	Transition	Energy (keV)	$P_{\gamma+ce}$ (%)
γ 4,3	9.75 (8)	13.2 (7)	γ 10,6	69.65 (7)	4.06 (13)
γ 11,10	39.06 (7)	0.492 (26)	γ 7,3	77.32 (8)	9.23 (22)
γ 9,7	44.07 (7)	8.93 (43)	γ 8,4	79.32 (9)	0.26 (13)
γ 5,4	50.14 (7)	7.68 (13)	γ 10,5	80.76 (7)	2.08 (31)
γ 9,5	61.50 (7)	1.941 (43)	γ 22,16	82.50 (22)	0.509 (9)
γ 7,4	67.57 (7)	5.33 (27)	γ 11,6	108.71 (7)	1.070 (31)

Transition	Energy (keV)	$P_{\gamma+ce}$ (%)	Transition	Energy (keV)	$P_{\gamma+ce}$ (%)
γ 9,4	111.64 (7)	1.144 (14)	γ 34,11	695.19 (9)	2.616 (26)
γ 13,11	117.30 (9)	1.791 (13)	γ 4,2	699.62 (6)	1.001 (22)
γ 11,5	119.82 (7)	3.323 (44)	γ 38,12	716.04 (16)	2.516 (26)
γ 17,12	122.98 (10)	2.697 (17)	γ 4,1	732.41 (6)	0.4748 (43)
γ 10,4	130.90 (7)	0.224 (17)	γ 6,2	760.87 (6)	20.4 (22)
γ 25,18	135.75 (11)	0.121 (18)	γ 5,1	782.55 (6)	13.898 (43)
γ 24,15	145.3 (6)	0.725 (17)	γ 47,20	827.4 (8)	0.548 (26)
γ 12,10	156.08 (8)	0.636 (44)	γ 35,6	844.58 (11)	0.60 (9)
γ 25,17	159.33 (11)	0.484 (13)	γ 37,9	850.34 (15)	0.151 (9)
γ 12,9	175.34 (8)	0.534 (17)	γ 50,21	891.61 (13)	0.647 (43)
γ 12,7	219.41 (8)	3.466 (35)	γ 11,1	902.37 (6)	4.575 (43)
γ 12,5	236.84 (8)	1.714 (26)	γ 40,6	962.01 (11)	0.0388 (43)
γ 37,27	258.30 (17)	0.0432 (43)	γ 44,9	1059.20 (22)	0.609 (17)
γ 17,10	279.06 (9)	0.48 (17)	γ 46,11	1066.00 (21)	0.501 (26)
γ 21,11	286.13 (8)	0.60 (9)	γ 1,0	1128.560 (40)	35.01 (6)
γ 34,25	295.86 (11)	3.008 (22)	γ 20,2	1141.90 (8)	1.86 (17)
γ 28,17	297.29 (11)	0.298 (30)	γ 45,6	1147.69 (9)	0.919 (22)
γ 14,6	298.70 (22)	3.008 (30)	γ 21,2	1155.70 (7)	7.005 (30)
γ 16,8	306.96 (10)	0.26 (13)	γ 2,0	1161.344 (40)	42.602 (43)
γ 20,10	311.39 (9)	2.106 (26)	γ 20,1	1174.69 (8)	0.609 (39)
γ 15,5	320.82 (12)	3.67 (30)	γ 46,5	1185.81 (21)	0.824 (35)
γ 18,9	321.90 (9)	0.475 (43)	γ 21,1	1188.49 (7)	2.503 (43)
γ 16,5	336.14 (9)	0.501 (26)	γ 23,2	1207.77 (9)	2.974 (26)
γ 29,17	340.26 (11)	0.216 (43)	γ 48,6	1225.80 (9)	2.266 (26)
γ 19,7	368.58 (11)	0.341 (35)	γ 23,1	1240.56 (9)	0.742 (39)
γ 19,5	386.01 (11)	0.203 (17)	γ 25,2	1268.90 (8)	0.734 (43)
γ 34,21	409.06 (10)	2.94 (30)	γ 51,9	1301.40 (12)	0.117 (17)
γ 27,12	416.70 (12)	0.824 (22)	γ 52,7	1352.07 (12)	1.77 (17)
γ 34,20	422.86 (11)	1.455 (22)	γ 28,2	1406.86 (9)	0.971 (13)
γ 33,19	425.16 (13)	0.35 (9)	γ 27,1	1436.08 (11)	2.383 (30)
γ 32,17	426.40 (32)	0.729 (13)	γ 29,2	1449.83 (9)	0.509 (17)
γ 31,15	446.32 (14)	0.570 (22)	γ 30,2	1503.62 (9)	2.007 (30)
γ 33,17	451.35 (11)	0.60 (9)	γ 31,1	1549.68 (10)	0.203 (17)
γ 26,7	505.80 (9)	0.047 (17)	γ 34,1	1597.55 (9)	1.778 (26)
γ 37,21	505.89 (15)	5.74 (13)	γ 36,2	1635.40 (21)	0.773 (17)
γ 25,6	508.04 (9)	1.08 (9)	γ 39,2	1720.55 (16)	1.373 (17)
γ 25,5	519.15 (9)	0.855 (26)	γ 40,1	1755.66 (11)	1.511 (43)
γ 33,12	574.33 (10)	0.311 (30)	γ 41,1	1819.60 (21)	0.345 (9)
γ 39,20	578.65 (17)	1.34 (22)	γ 42,1	1831.93 (40)	1.032 (13)
γ 38,17	593.06 (17)	0.846 (22)	γ 43,1	1885.23 (40)	0.237 (13)
γ 29,10	619.32 (9)	1.817 (30)	γ 49,1	2035.39 (12)	0.423 (13)
γ 29,6	688.97 (9)	1.101 (26)	γ 51,1	2145.44 (12)	3.164 (30)

1.3. Beta transitions

The β transition probabilities P_β are given in Table 11 for each level, the sum being 100% by construction.

It is noteworthy that no β transition to the ground state and the 1851.22-keV level was necessary to balance the decay scheme. In [2014TI05], a ≈2% branching ratio to the ground state was considered based on systematics of log *ft* values in this mass region. However, there is no experimental evidence for such a transition, which would be first forbidden unique and thus strongly disfavoured compared to the other transitions.

The average energy of the beta spectra and the log *ft* values were determined using the BetaShape program, version 2.3.1. This version includes precise atomic corrections (screening, exchange and overlap) that are of importance for such low-energy transitions [2023MO21].

Table 11 – Beta transition probabilities per 100 decays.

Level #	Energy (keV)	P_β (%)	Level #	Energy (keV)	P_β (%)
0	0	0	27	2564.65 (10)	3.164 (37)
1	1128.560 (40)	1.13 (13)	28	2568.22 (8)	1.269 (33)
2	1161.350 (40)	3.0 (22)	29	2611.19 (8)	3.64 (6)
3	1851.22 (6)	0	30	2664.98 (8)	2.007 (30)
4	1860.97 (5)	0	31	2678.25 (9)	0.773 (28)
5	1911.11 (5)	6.48 (45)	32	2697.33 (31)	0.729 (13)
6	1922.22 (5)	6.3 (22)	33	2722.28 (8)	1.26 (13)
7	1928.54 (5)	0	34	2726.12 (8)	11.79 (31)
8	1940.29 (7)	0	35	2766.80 (10)	0.60 (9)
9	1972.61 (5)	10.14 (44)	36	2796.76 (21)	0.773 (17)
10	1991.87 (5)	0.82 (38)	37	2822.95 (14)	5.93 (13)
11	2030.93 (5)	3.95 (12)	38	2863.99 (15)	3.362 (34)
12	2147.95 (6)	0	39	2881.91 (16)	2.71 (22)
13	2148.23 (7)	1.791 (13)	40	2884.23 (10)	1.550 (43)
14	2220.92 (21)	3.008 (30)	41	2948.17 (21)	0.345 (9)
15	2231.93 (11)	2.37 (30)	42	2960.50 (40)	1.032 (13)
16	2247.25 (7)	0.25 (13)	43	3013.80 (40)	0.237 (13)
17	2270.93 (8)	0	44	3031.81 (21)	0.609 (17)
18	2294.51 (8)	0.354 (46)	45	3069.92 (8)	0.919 (22)
19	2297.12 (10)	0.20 (9)	46	3096.93 (20)	1.325 (43)
20	2303.26 (7)	1.23 (28)	47	3130.7 (8)	0.548 (26)
21	2317.06 (6)	0.79 (35)	48	3148.03 (7)	2.266 (26)
22	2329.75 (21)	0.509 (9)	49	3163.97 (11)	0.423 (13)
23	2369.13 (8)	3.716 (47)	50	3208.67 (12)	0.647 (43)
24	2377.2 (6)	0.725 (17)	51	3274.02 (11)	3.280 (35)
25	2430.26 (7)	0.26 (10)	52	3280.62 (11)	1.77 (17)
26	2434.34 (7)	0.047 (17)			

2. Atomic data

The fluorescence yield data, the relative K X-ray emission probabilities and the ratios P(KLX)/P(KLL) and P(KXY)/P(KLL) were taken from Schönfeld et al. [1996SC06].

The Auger electron and X-ray absolute probabilities were determined with the EMISSION program [2000SC47] from the related decay data.

3. Consistency

Consistency of the recommended data was checked by calculating with Saisinuc [2008DUZX] the total average emission energy per decay for all emissions involved in the ^{129m}Sn decay process. This total emission energy, including atomic processes, is 3659 (82) keV.

The 1851-keV level de-excitation was not included in the decay scheme because of its half-life of 17.4 (3) min. In [1987ST23], this metastable state is estimated to decay at 85% through beta transitions and at 15% by isomeric γ transitions (IT) with two γ-rays in coincidence at 722 and 1128 keV. Detailed results from [1987STZO], on which the present evaluation was based, are however contradictory as one can deduced from the γ-ray and conversion electron measurements an IT decay at 8.158 (43)% and a beta decay at 91.842 (43)%.

The amount of energy hold by the 1851-keV level is deduced from its relative contribution in the ^{129}Sb de-excitation scheme as 415 (10) keV. Summing up with the total emission energy, one obtains 4074 (82) keV, in perfect agreement with the adopted Q-value of 4074 (27) keV that includes the energy of the ^{129m}Sn metastable level.

4. Recommendations of measurements

The works from [1982HU09] and [1987ST23, 1987STZO] do not allow establishing a firm decay scheme. New γ-γ coincidence measurements are necessary, and new conversion electron measurements would be of great help, especially at low energy. Spins, parities and multipolarities are mostly based on [1987STZO] assignment, which can only be considered as a tentative. A better assignment is needed.

It could also be interesting to measure the β spectra, or at least the total β spectrum, from which one could deduce the β feedings. In particular, this could be assessing P_β to the ground state and the 1851.22-keV level of ^{129}Sb.

A Total Absorption Spectrometry (TAS) measurement of ^{129m}Sn decay could solve most of these issues.

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