EXCITED STATES OF ^{119}Sb

M. Gąsior, H. Niewodniczański†, A. W. Potempa and J. Sieniawski

Institute of Nuclear Physics, Cracow*

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A magnetic beta-spectrometer of high transmission was used to measure the energies and intensities of the internal conversion electron lines following the decay of ^{119m}Te. The existence of the 116.4 keV and 871.2 keV transitions was confirmed. Several lines of very weak intensities, whose decay times are near the value of the ^{119m}Te life-time, were observed for the first time. The conversion coefficients were evaluated for most of the observed transitions. The following spin values for the excited states of ^{119}Sb are suggested: 0 keV — $5/2^-$, 270.3 keV — $7/2^+$, 1048.1 keV — $7/2^+$, 1212.6 keV — $9/2^+$, 1249 keV — $9/2^+$, 1365.8 keV — $11/2^-$, 1407 keV — 9/2, $11/2^+$, 2129 keV — $9/2^-$, 2226 keV — 9/2, $11/2^+$ and 2278 keV — 9/2, $13/2^-$.

Introduction

Recent researches by means of scintillation, germanium and magnetic spectrometers on the decay schemes of ^{119m}Te and ^{119}Te and studies of the (He^3, d) reaction on ^{118}Sn [1, 3, 4, 5, 6] have revealed some thirty excited states of energies lower than 3 MeV for the ^{119}Sb nucleus. Experimental data indicate that among them there are also levels with negative parity. The theoretical calculations of Pashkevich [8], Kisslinger [9] and de Pinho [10] give a smaller number of excited states and do not anticipate the appearance of any negative parity states in this energy range. Therefore, the basic purpose of this study was to determine the spins and parities of the excited states of the ^{119}Sb nucleus.

Sources and apparatus

The $^{119+119m}$Te sources were obtained by bombarding a target of tin of natural isotopic composition or tin enriched in ^{116}Sn with 24 MeV alpha particles in the U-120 cyclotron at the Institute of Nuclear Physics in Cracow. In each irradiation the current was $I \approx 7$ μA and the irradiation lasted about ten hours. Isotopes of tellurium with mass numbers ranging from 114 to 127 were produced in the (α, n) and $(\alpha, 2n)$ reactions. The tellurium was separated from the tin and deposited on base layers for spectrometric sources by the vacuum

* Address: Instytut Fizyki Jądrowej, Kraków 23, ul. Radzikowskiego, Polska.

† Deceased.

evaporation technique [13]. Thin sources were received thus, and there were no detectable impurities of Sb or Sn in them. The sources were found to contain the activities: ^{116}Te, ^{118}Te, $^{119+119m}$Te, $^{121+121m}$Te, ^{123m}Te, ^{125m}Te and $^{127+127m}$Te. The measurements were performed on a coreless toroidal beta-soectrometer of high transmission (up to 20 per cent) [14].

Results of measurements and calculations

Several series of measurements of the internal conversion electron spectra were made in the 20 keV to 1200 keV electron energy range. The spectrometer transmission was 14 and 20 per cent, and the corresponding resolving powers were 0.75 and one per cent.

The results of measurements of the intensities and energies of the conversion lines are given in Table I. The third column of the table gives the results of Svedberg [3] for comparison. Our values of gamma-transition energies are in conformity within limits of error with

TABLE I

Energies and relative intensities of internal conversion lines

E_e (keV)	I_e	I_e [3]	Interpretation	
65.2	6.7±1.0		K— 95.7	^{119m}Te
92.0	~1		L— 95.7	^{119m}Te
111.9	1.45±0.30		L—116.4	^{119m}Te
122.7	1000	1000	K—152.8	^{119m}Te ^{a}
133.5	53±2	54±20	K—164.1	^{119m}Te ^{a}
148.7	132±4		L—152.8	^{119m}Te
152.1	20±6		M—152.8	^{119m}Te
240.9	290±5	330±25	K—270.3	^{119m}Te
266.8	47.0±2.5		L+M—270.3	^{119m}Te
294	0.36±0.10		K—324.5	^{119m}Te or ^{118}Te
307	0.16±0.11		K—337.6	^{119m}Te or ^{118}Te
338.5	0.24±0.09		K—369	^{119m}Te or ^{118}Te
364.4	0.42±0.07		K—395	^{119m}Te or ^{118}Te
795.5	0.15±0.04		K—826	^{119m}Te or ^{118}Te
827.5	0.15±0.04		K—858	^{119m}Te or ^{118}Te
840.7	0.11±0.03		K—871.2	^{119m}Te
883.8	3.36±0.10	3.3±1.1	K—912.4	^{119m}Te ^{a}
911.7	2.29±0.15	2.1±0.7	K—942.3	^{119m}Te ^{a}
949.3	1.89±0.14	1.9±0.8	K—(976+979)	^{119m}Te ^{a}
981.4	0.60±0.13	1.2±0.8	K—1012.8	^{119m}Te ^{a}
1021.5	1.20±0.08	1.0±0.7	K—1048.1	^{119m}Te ^{a}
1051.5	0.19±0.08		K—1080.8	^{119m}Te ^{a}
1061.0	2.10±0.99	2.1±0.8	K—1095.4	^{119m}Te ^{a}
1107.0	2.16±0.10	1.2±0.7	K—1136.7	^{119m}Te ^{a}
1132.4	0.27±0.04		L+M—1136.7	^{119m}Te ^{a}
1180.8	16.6±0.3	14.5±0.9	K—1212.6	^{119m}Te ^{a}

^{a} Energy of the transition from Ref. [4].

those obtained in the studies [4] and [6]. Henceforth we shall use the energy values given in Ref. [4], as they are burdened with smaller errors than our values.

ACTA PHYSICA POLONICA Vol. XXXV (1969) Fasc. 3

Table I presents a number of new lines of internal conversion electrons which in most cases may arise due to the decay of ^{119m}Te ($T_{1/2}$ = 4.75 d) or ^{118}Te ($T_{1/2}$ = 6 d). These transitions, except for the 95.7 keV line, cannot be set within the decay scheme of ^{119m}Te without introducing new levels. The K-95.7 keV line decays with a half-life of $T_{1/2}$ = (4.65±0.4) days; this transition does not belong to ^{118}Te. With these data as the basis, the 95.7 keV transition has been drawn in the decay scheme of ^{119m}Te as shown in Fig. 2.

The results of calculations of the internal conversion coefficients are given in Table II and Fig. 1. In the calculations it was assumed that the 152.8 keV transition is of the El type. This assumption has been made on the basis of results angular correlation measurements [5]. Our measurements of the ratio $K/L+M = 6.6\pm0.5$ also agrees with this assumption. In

TABLE II

Internal conversion coefficients

E_γ(keV)	I_γ [a]	$\alpha_K \times 10_3$	Proposed multipolarity	
			present work	Graeffe *et al.* [5]
116.4	0.7±0.1	12±6 [b]	E1	
152.8	99±5	49.5 [c]	E1	E1
164.1	1.7±0.2	153±21	M1 (≤ 50% E2)	
270.3	39±2	36.5±2.2	M1 (≤ 50% E2)	M1 (≤ 20% or 80-90 E2)
871.2	0.4±0.1	1.3±0.7	M1 E1 E2	
912.4	10.2±1.0	1.66±0.22	M1 E2	M1 (20–70% E2)
942.3	6.5±0.5	1.72±0.25	M1 (≤ 70% E2)	M1 (26–60% E2)
976	8.4±1	1.10±0.20	M1 E2 [d]	
1012.8	3.3±1	0.89±0.30	E2 (≤ 30% M1)	
1048.1	4.7±0.4	1.25±0.20	M1 E2	
1080.8	2.3±0.3	0.41±0.20	E1	
1095.4	3.4±0.3	3.0±0.4	M2	M2
1136.7	11.7±0.6	0.91±0.09	E2 (≤ 30% M1)	M1 E2
1212.6	100±5	0.81±0.06	E2 (≤ 20% M1)	E2
1365.8	1.9±0.3			E3
2089.4	5.9±0.5			M1 E1 E2

[a] I_γ values from Ref. [4] and [6];
[b] There is a given α_L;
[c] Theoretical α_K;
[d] Lines of electrons are not separated but the aggregate α_K indicates that both transitions are of the M1 or E2 type.

the calculation of the internal conversion coefficients the values of gamma-transition intensities obtained by Graeffe [6] were used. When the difference between the values of gamma-transition intensities given in references [4] and [5] was greater than the limit of measurement error, then their arithmetic mean was used in subsequent calculations. These values are given in the second column of Table II. The fifth column of this table contains data on the multipolarity of the transitions obtained from angular correlation measurements [5].

ACTA PHYSICA POLONICA Vol. XXXV (1969) Fasc. 3

ACTA PHYSICA POLONICA Vol. XXXV (1969) Fasc. 3

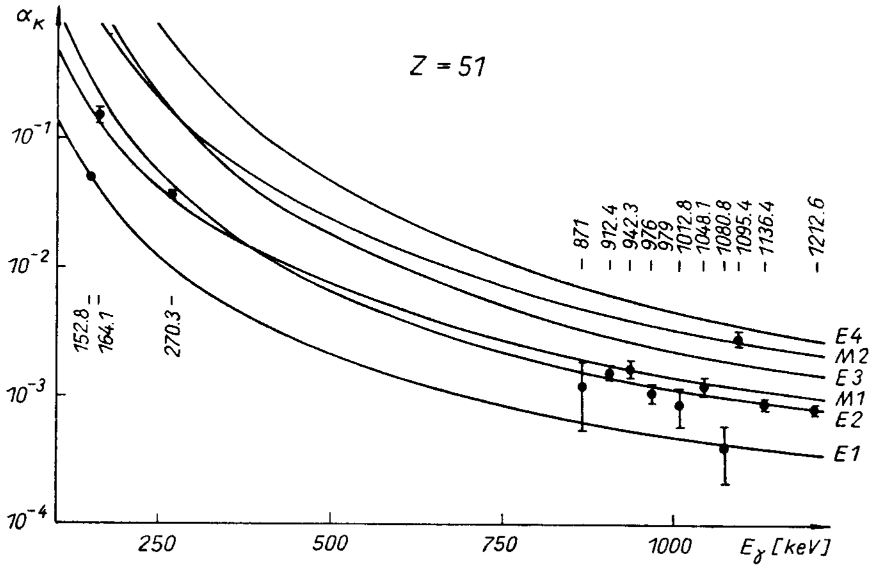

Fig. 1. Internal conversion coefficients

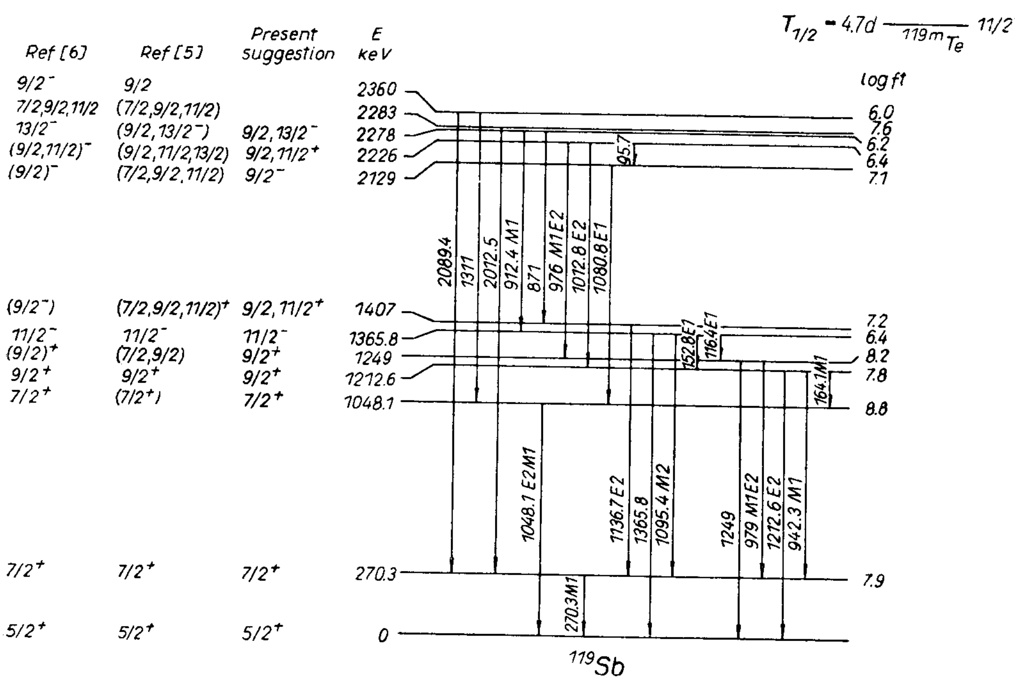

Fig. 2. Energy level scheme of ^{119}Sb obtained from the decay of ^{119m}Te

Spin and parities of levels

The spins and parities of most of the ^{119}Sb levels were determined uniquely. For this, use was made of the internal conversion coefficients obtained in the present work, the gamma-transition intensities and log ft values measured by Berzins [4] and Graeffe [6], and the results of angular correlation measurements by Berzins [5].

Assuming as the reference points the spins and parities of the levels 0 keV ($5/2^+$) and 1365.8 keV ($11/2^-$) determined in Ref. [5], we can assign the parities to the following levels:

270.3 *keV level*: "+" parity, because the 270.3 keV transition is of type M1, E2, or M1+E2.

1048.1 *keV level*: "+" parity, because the 1048.1 keV transition is of type M1, E2 or M1+E2.

1212.6 *keV level*: "+" parity, because the 1212.6 keV transition is of type E2.

1249 *keV level*: "+" parity, because the 116.4 keV transition is of type E1.

1407 *keV level*: "+" parity, because the 1136.7 keV transition is of type M1, E2 or M1+E2.

2129 *keV level*: "—" parity, because the 1080.8 keV transition is of type E1.

2226 *keV level*: "+" parity, because the 1012.8 keV transition is of type M1, E2 or M1+E2.

2278 *keV level*: "—" parity, because the 912.4 keV transition is of type M1.

Spin of the 1249 keV level

According to the results of angular correlation measurements [5] the spin of this level is either 7/2 or 9/2. The type of the 116.4 keV transition (E1) excludes the possibility of it being equal to 7/2. Hence, the spin of the 1249 keV level is $9/2^+$.

Spin of the 1407 keV level

The type of the 1136.7-keV transition (E2) restricts the possible upper value of the spin of this level to $11/2^+$. The value of log $ft = 7.2$ for the beta-transition from ^{119m}Te ($I = 11/2^-$) to this level indicates that this is a forbidden transsition of first order at most, with $\Delta I = 0, 1$ ($\Delta I = 0, 1$ with change of parity log $ft = 7.5 \pm 1.5$; $\Delta I = 2$ with change of parity log $ft = 8.5 \pm 0.7$ [12]). Hence, its spin must be greater than or equal to 9/2. Therefore, the spin of the 1407 keV level is either $9/2^+$ or $11/2^+$.

Spin of 2129 keV level

Owing to the type of the 1080.8 keV transition (E1) the spin of the 2129 keV level cannot be greater than 9/2. Should the spin be equal to 7/2, then the beta-transition to this level would be an absolutely forbidden one ($\Delta I = 2$ with change of parity log $ft = 8.5 \pm 0.7$) and the value of log ft would be greater. Hence, the value of the spin of the 2129 keV level is $9/2^-$.

Spin of the 2226 keV level

The type of the 1012.8 keV transition (E2) and the value log $ft = 6.4$ for the beta-transition to this level from ^{119m}Te ($I = 11/2^-$) allow three values of its spin, *viz.* 9/2, 11/2 and $13/2^+$. Angular correlation analysis of the 976 keV — 979 keV gamma-gamma cascade [5], considering that the 1249 keV level's spin is equal to $9/2^+$, enables us to eliminate the value 13/2. Hence, the spin of the 2226 keV level is $9/2^+$ or $11/2^+$.

In Ref. [6] the spins of levels are determined with the use of the internal conversion coefficients calculated on the basis of the intensities of internal conversion lines measured in Ref. [3]. These measurements are made with large error, however, and this is why there are discrepancies between our parity determinations and those in Ref. [6].

The fact that the 1365.7 keV ($11/2^-$), 2129 keV ($9/2^-$) and 2278 keV ($9/2$ or $13/2^-$) levels of negative parity are observed points to the necessity of introducing essential changes in the applied theoretical description [8, 9, 10], which only anticipates states having " + " parity.

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