NUCLEAR SPECTROSCOPY OF NEUTRON RICH A=147 NUCLIDES: DECAY OF ^{147}Cs, ^{147}Ba AND ^{147}La

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Abstract

A study of the beta decay of neutron rich nuclides of the A=147 chain was carried out at the TRISTAN isotope separator. Half lives of ^{147}Cs, ^{147}Ba and ^{147}La were measured. Six gamma lines are assigned to ^{147}Cs decay. A decay scheme for ^{147}Ba with levels up to 2 MeV is proposed for the first time. A partial decay scheme for ^{147}La is proposed, which confirms the previously existing one, with five new levels added from the present work.

1. Introduction

Recent developments in the field of on-line isotope separation made the transition region 141<A<148 more and more accessible for detailed nuclear structure studies. A systematic study of the short-lived, neutron-rich nuclides in this region has been undertaken now at the TRISTAN ISOL facility at Brookhaven National Laboratory. As a part of this effort a preliminary study of the decay of ^{147}Cs, ^{147}Ba and ^{147}La is here reported. Previously reported data on these members of the A=147 chain is very limited. The half life of ^{147}Cs was first measured at the OSTIS facility; the values reported were 0.235 ± .010 sec[1] and 0.218 ± 0.009 sec.[2] Three gamma lines were associated with ^{147}Cs decay 85, 181 and 246 keV.[2] The half lives of ^{147}Ba and ^{147}La were first measured at the SOLIS facility and they are reported to be 0.72 ± 0.07 sec for ^{147}Ba and 4.4 ± 0.5 sec for ^{147}La.[3] No gamma lines were reported for the ^{147}Ba decay. For ^{147}La a partial decay scheme was proposed with 11 levels and 20 transitions.[4] In this work the decay of ^{147}Ba was studied in detail and a decay scheme is proposed for the first time. For ^{147}La the existing decay scheme is confirmed and further improved.

2. Experimental Methods

The TRISTAN isotope separator facility, which was recently installed at the High Flux Beam Reactor at Brookhaven Natl. Lab. is described in ref. 5. Ion beams of Cs and Ba isotopes were produced by an integrated target-ion source system[6] which is similar to a previously reported version.[7,8] The target consisted of 5 gr of ^{235}U coated on graphite cloth and heated to ∿2000°C. The target was exposed to a neutron flux of ∿1.5 x 10^{10} n/cm^2/sec. Cs and Ba fission products which evaporated from the target were ionized with high efficiency by the surface ionization process on a Re surface. At the point of deposition, A=147 beam produced a source intensity of ∿ 1 μCi.

Half lives were determined by multiscaling gamma activity, using a gamma-x HPGe detector and also by multiscaling beta activity with a 2π plastic scintilator. Gamma-gamma coincidence events were recorded with two Ge(Li) detectors. The data acquisition and analysis system which supported these experiments is described in ref. 5.

The ion beams were implanted on a moving tape collector, cycled to optimize the experiment for the desired activity. ^{147}Cs and ^{147}Ba activities were detected at the point of deposition. To reduce ^{147}La activity the tape collector was moved every two seconds. ^{147}La was detected at a measuring station 60 cm from the point of deposition. The tape collector was cycled so that the beam was deposited for 8 sec, and then the tape was moved to an intermediate point to allow ^{147}Cs and ^{147}Ba activities to decay for 8 sec. The source was then moved to the detection station for an 8 sec counting interval.

3. Results

3.1 ^{147}Cs Decay

For the half life of ^{147}Cs a value of 0.212 ± 0.010 sec was obtained from beta decay curves and a value of 0.3 ± 0.1 sec was obtained from gamma multiscaling of the 84.7 and 110.0 keV lines. These values are in good agreement with the previous measurements[1,2] and the prediction derived from semiempirical systematics.[3] Six gamma lines were associated with the ^{147}Cs decay: 84.7, 110.0, 280.1, 312.6 and 366.7 keV. The 181.0 keV line, which decays with the ^{147}Cs half life, is the first 2^+ to 0^+ transition of ^{146}Ba and is a result of delayed neutron branching. This is based on the coincidence relations of this line. Analysis of the beta decay curve shows that the ratio of direct production of ^{147}Cs to ^{147}Ba is ∿1:10 but the very low gamma intensity (less than 2% of ^{147}Ba) indicates that high percentage of the beta decay goes to ^{147}Ba ground state.

3.2 ^{147}Ba Decay

The half life of ^{147}Ba was determined by beta and gamma multiscaling; the average value was 0.93 ± 0.05 sec which is somewhat higher than the previously reported values.[2,3]

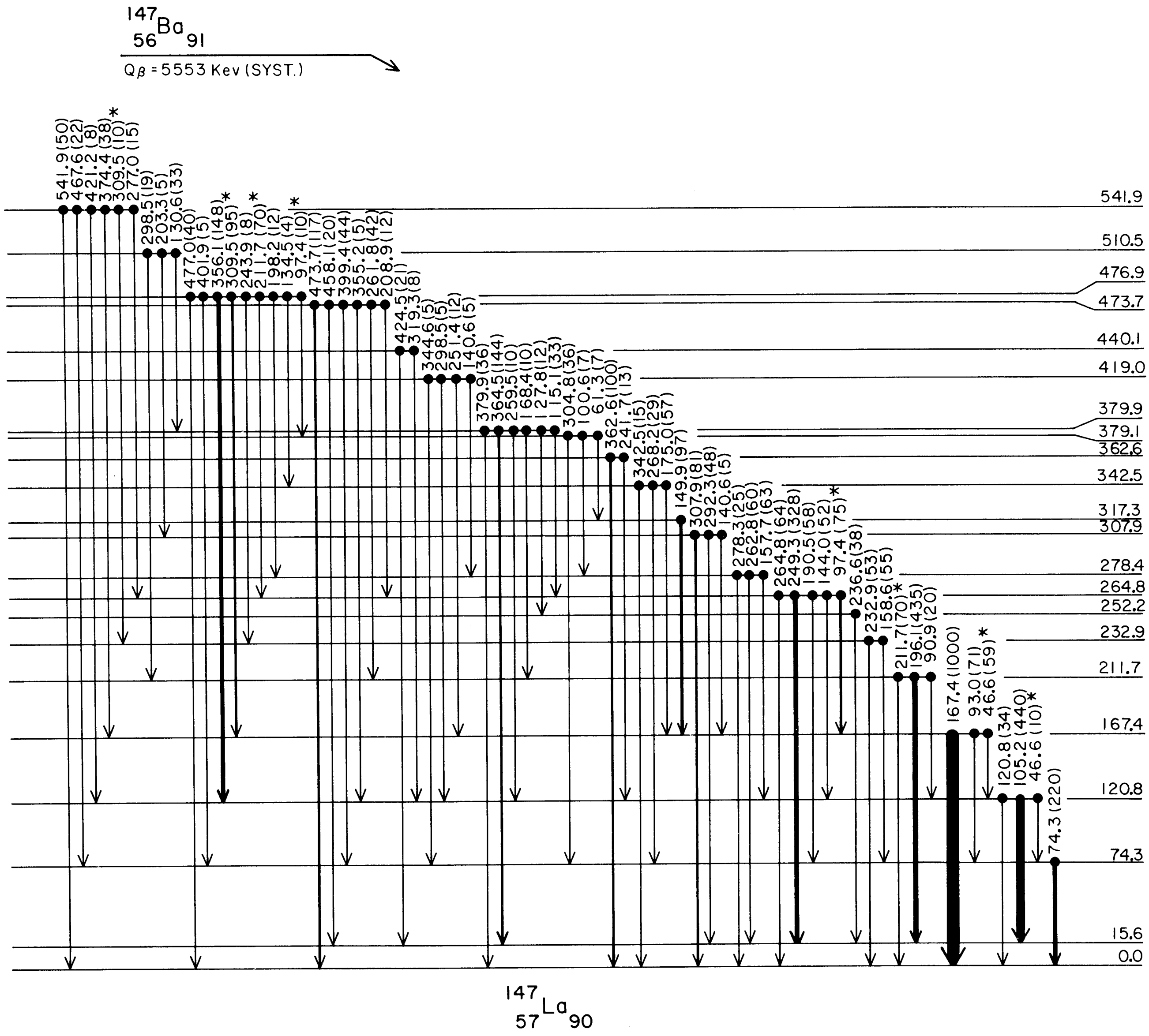

Fig. 1 A proposed decay scheme for ^{147}Ba; levels up to 600 keV. *Multiple placement.

More than 200 gamma lines were assigned to ^{147}Ba decay by their decay and their coincidence relations were established using ten million coincidence events. A partial coincidence matrix is given in Table I and the decay scheme, proposed for the first time, is shown in figs. 1 and 2.

The starting point for building the decay scheme was the level at 167.4 keV which is based mainly on the intensity of the transition. The coincidence lists and the coincidence intensities suggest that the 97.4, 144.0, 190.5, 249.3 and 264.8 keV all depopulate the same level. The fact that the 97.4 line is in coincidence with 167.4 keV and, the high intensity of the 249.3 line, fix a level at 264.8 keV. The coincidence relations of the 157.7 and 144.0 lines indicate that the 105.2 and 120.8 keV lines depopulate the same level. The high intensity of the 105.2 keV line and the place of the 144.0 transition place this level at 120.8 keV. This structure necessitates the assumption of a level at 15.6 keV. A 15.6 keV transition could not be observed because the detector used could not see lines below ∿30 keV. The rest of the decay scheme was constructed around this basic skeleton to fit the coincidence relations.

3.3 ^{147}La Decay

The half life of ^{147}La was determined by multiscaling the seven highest intensity gamma lines associated with its decay. The weighted average obtained is 4.48 $\pm$ 0.08 sec. This is in good agreement with the previously reported value,[3] but the precision is improved.

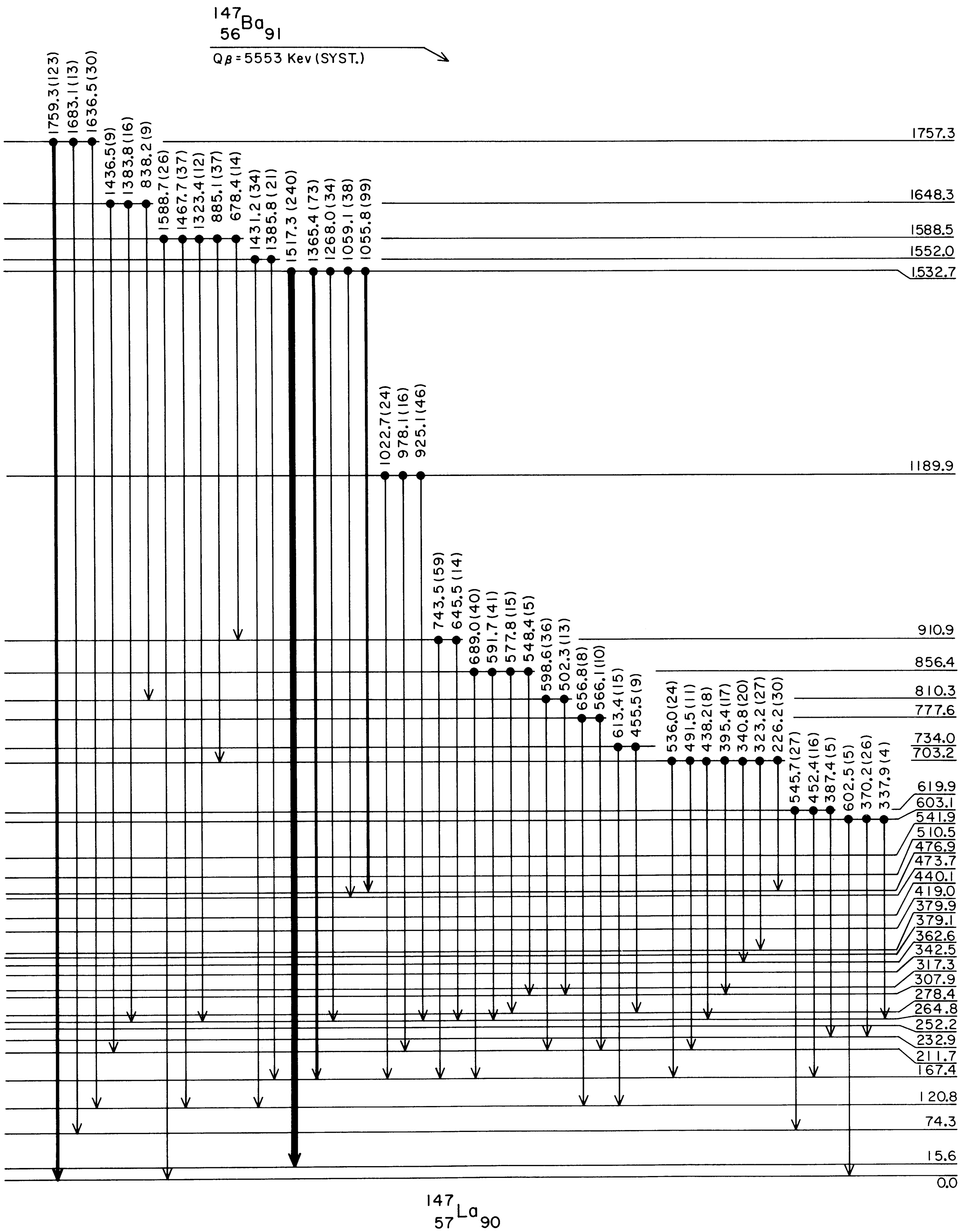

Fig. 2 A proposed decay scheme for ^{147}Ba: decay pattern of levels above 600 keV.

The partial decay scheme proposed is shown in fig. 3. The previously existing decay scheme is substantially confirmed. Two levels at 401.0 and 402.3 keV could be resolved. Five more levels were added at 273.8, 505.0, 558.2, 785.8 and 831.1 keV.

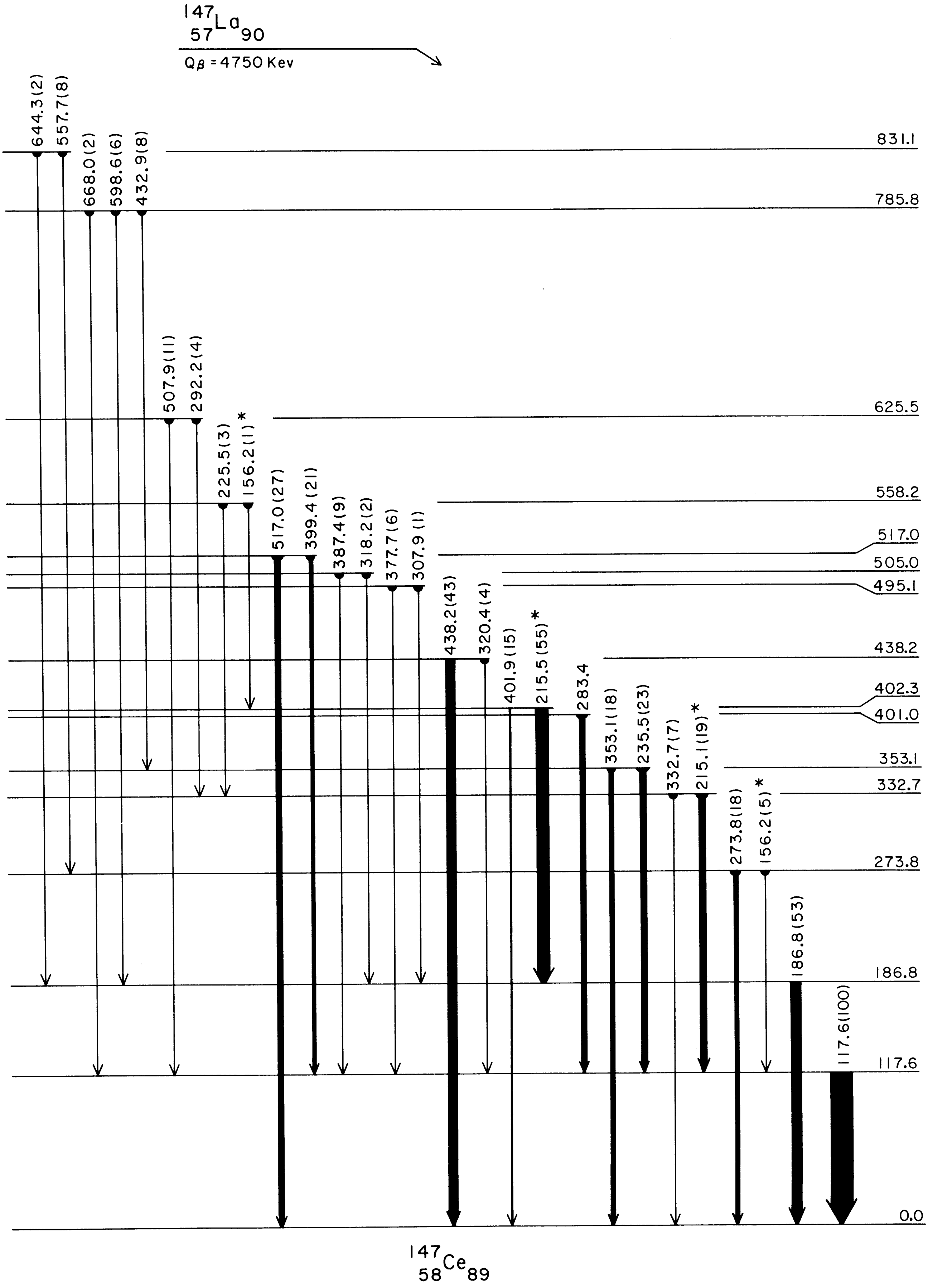

Fig. 3 A partial decay scheme for ^{147}La. *Multiple placement.

The level at 495.1 keV was confirmed but the 161.5 transition, associated with it, was not seen and the 495.3 keV is not the ground state transition of this level since it is in coincidence with the 215 keV doublet.

4. Discussion

No attempt has as yet been made to arrive at any spin or parity assignments for the ^{147}Ba levels. For the ground state, $7/2^+$ and $5/2^+$ seem to be possible assignments. The absence of beta feeding and conversion coefficient data make the relative intensity of the transitions of low-lying levels too uncertain for identifying the multipolarities of the transitions involved. Therefore the work on ^{147}Ba decay should be continued. The level at 15.6 keV should be confirmed by future low-energy gamma spectroscopy, and beta-gamma coincidence experiments will be needed to confirm the decay scheme proposed and to supply information about beta feeding and conversion coefficients.

For the ground state of ^{147}Ce the assignment of $J^\pi = 5/2^-$ seems to be reasonable from the trend found in the Ce isotopes ($3/2^-$ for ^{143}Ce[9] and $5/2^-$ for ^{145}Ce[10]) and from the trend in the N=89 isotones ($5/2^-$ for both ^{149}Nd[11] and ^{151}Sm [12]). Intensity balances suggest that the 117.6 and 186.8 keV transitions are M1 or E2 transitions which is expected from the trend found in the neighboring N=89 isotones. The intensity balances indicate significant beta feeding to the 117.6 keV level and very little or no feeding to the 186.8 keV level, in agreement with the previously reported beta-gamma coincidence work.[13]

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Table I

A partial coincidence matrix for ^{147}Ba decay

Gate (keV)	Gamma lines in coincidence (keV)
46.6	74.3 97.4 105.2 120.8 149.9 175.0 211.7 309.5 1055.8 356.1
74.3	93.0 97.4 144.0 158.7 175.0 190.5
90.9	105.2 120.8
93.0	74.3 97.4 149.9 175.0 211.7 309.5
97.4	74.3 93.0 105.2 149.9 167.4 211.7 925.1 1055.8
105.2	90.9 97.4 144.0 149.9 157.7 175.0 211.7 309.5 356.1 1055.8 1268.1
144.0	74.3 105.2 120.8 211.7 925.1 1268.1
149.9	93.0 97.4 105.2 167.4 1055.8
157.7	105.2 120.8
158.6	74.3 309.5
167.4	97.4 149.9 175.0 309.5 925.1 1055.8 1268.1
175.0	74.3 93.0 105.2 167.7
190.5	74.3 211.7 925.1 1268.1
196.1	598.6
211.7	74.3 93.0 97.4 105.2 144.0 167.4 190.5 249.3 598.6 1055.8
232.9	309.5
249.3	211.7 925.1 1268.1
264.8	211.7 925.1 1268.1
307.9	
309.5	93.0 105.2 158.7 232.9 1055.8
356.11	74.3 105.2 120.8 1055.8
362.6	
364.5	
473.7	
598.6	196.1 211.7
925.1	97.4 144.0 167.4 190.5 249.3 264.8
1055.8	93.0 97.4 105.2 167.4 211.7 309.5 356.1
1268.1	105.2 144.0 167.4 190.5 249.3 264.8

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