Decay of ^{143}Ba to levels of the odd-proton $N=86$ nuclide ^{143}La

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The level structure of ^{143}La has been investigated by measurement of gamma-ray and conversion-electron singles, gamma-gamma coincidence, and gamma-gamma angular correlation spectra following the decay of 15.0-s ^{143}Ba. Comparison of the observed structure of ^{143}La with the structures of isotopic La and isotonic $N=86$ nuclides, as well as those of the adjacent Cs isotopes and $N=84$ isotones, suggests the presence of unusual low-lying $\frac{3}{2}^+$ and $\frac{5}{2}^-$ levels that are not readily accounted for by theoretical calculations. The observed structures suggest that the deformation in this mass region is influenced by different factors than that of the nuclides above $Z=64$, and that reflection asymmetric structures play an important role in the structure of the nuclides in the $A=145$ mass region.

I. INTRODUCTION

Recent studies[1–4] of the structure of the neutron-rich even-Z Ba and Ce nuclides have provided limited experimental support for the proposition[5] that reflection asymmetric structures play a role in the structure of the low-lying levels in the region near ^{145}Ba. The most important evidence comes from the identification of alternating parity bands in ^{142,144,146}Ba and ^{146}Ce by Phillips *et al.* that have significant $E1$ branching in competition with $E2$ crossover transitions.[3,4] Studies of the structures of the adjacent odd-mass nuclides ^{143,145}Ba and ^{147}Ce have not revealed the parity doublet structures[1,2] comparable to those observed in the Ra and Ac nuclides.[6,7] But, low-lying positive-parity levels were identified among the predominantly negative-parity levels that do suggest an enhanced role for reflection asymmetric structures. The change in sign of the magnetic dipole and electric quadrupole moments between ^{143}Ba and ^{145}Ba, both of which have ground-state spin and parity of $\frac{5}{2}^-$, the observed structures of these two nuclides, and the systematics of the $N=87$ and 89 isotones are not readily described by a single model.

The structures of the adjacent odd-Z Cs nuclides are also of interest because the ground-state spin of both ^{143}Cs and ^{145}Cs is $\frac{3}{2}$ in contrast with the expected $g_{7/2}$ shell model orbital found near the $N=82$ closed shell[8,9] in $^{133-141}$Cs. These spin changes, along with the increases in quadrupole moment observed with increasing neutron number, have been taken as an indication of the onset of deformation. As no level structures had been reported for ^{143,145}Cs, the degree of deformation and its effect on the structure can only be inferred from the measured moments.

To further investigate the onset and character of this possible deformation and to identify low-lying negative-parity levels among the predominantly positive parity level structures, a systematic investigation[10,11] of the structure of the odd-mass Cs, La, and Pr nuclides has been carried out at the on-line mass-separator facility TRISTAN. In previous publications results for ^{139,141}La and for ^{139,141,143}Cs have been presented.[12,13] In this paper, results for ^{143}La are described while the results for ^{145,147}Pr will be presented in subsequent papers.[14,15]

Prior to the studies of Pacer *et al.*[16] and Schussler *et al.*[17] very little information on the level scheme of ^{143}La was known. The level structures presented in those studies are generally in good agreement for the levels observed. Several earlier studies of mass-separated ^{143}Ba decay dealt primarily with half-life determination.[18–24] The study by Talmi *et al.*[22] also attributed eight gamma-ray transitions to ^{143}Ba decay. The most recent half-life determination, reported to be 15.2±0.2 s by Engler *et al.*[25] is slightly higher than the 14.5±0.5 s value reported by Pacer *et al.* As a value of 15.0 is within the limits of the uncertainties reported by both groups, we have shown that value on the level scheme. Absolute intensities in the mass 143 fission product chain have been reported by Sohnius *et al.*[25] A subsequent publication by Rapaport and Gayer reports gamma-ray and conversion electron energies and intensities with no significant changes proposed in the level structure.[26] Conversion-electron measurements in that work are more extensive than those reported by Schussler *et al.*[17] but fewer gamma rays were reported than either of the previous studies.

II. EXPERIMENTAL PROCEDURES AND RESULTS

A. Experimental measurements

The experiments were performed at the TRISTAN on-line mass separator facility which is on-line to the High Flux Beam Reactor at Brookhaven National Laboratory. The facility and its operation have been discussed in previous publications.[27,28] A positive surface ionization source[29] was used to extract 1.8-s ^{143}Cs and its 15.0-s ^{143}Ba daughter for the two different parts of this experiment. The ion source contained a target of highly enriched uranium as UO_2 imbedded in a graphite cloth, which was exposed to a thermal neutron flux of $2\times10^{10} n\ \mathrm{cm}^{-2}\ \mathrm{sec}^{-1}$ from the High Flux Beam Reactor.

Gamma-ray measurements were conducted at the point of deposit of the moving-tape collector. The mass-separated beams were deposited on an aluminized Mylar tape that could be moved periodically to remove daughter activities and enhance the activity due to ^{143}Ba decay. The large ratio of cesium to barium in the extracted beam required the collection cycle to start with a short deposition period, followed by a period of beam deflection without data accumulation that allowed the 1.8-s ^{143}Cs precursor to decay to daughter ^{143}Ba. Data were then acquired for 30 s before the tape was moved and the cycle reinitiated. The tape collector was operated with a 15-m continuous tape loop that was periodically replaced to avoid build-up of daughter activity. No gamma rays from the decay of the 14-min ^{143}La daughter nucleus were observed in the accumulated spectra.

Four large volume Ge detectors were placed in a plane around the deposition point for collection of singles and coincidence data. The full width at half maximum (FWHM) of the detectors was less than 2.0 keV for the 1.33-MeV gamma ray of ^{60}Co. The four detectors were positioned at 90° to each other, permitting angular correlation data to be obtained at 90° and 180°. The gain of the detectors for the coincidence experiments was adjusted to cover the energy range up to 2 MeV. Additional singles and calibration spectra extended to 3 MeV.

Conversion electron measurements were made on a separate beam line equipped with a Ge detector, a cooled Si(Li) detector and a moving-tape collector. The same collection cycle was used to accumulate a singles gamma-ray spectrum with a Ge detector, and an electron spectrum with a Si(Li) detector that had a FWHM value of 1.8 keV for the 630-keV *K* line of ^{137}Cs. The gamma-ray and conversion electron detectors were gated by pulses from a plastic scintillator which was covered with a thick Al plate. This plate absorbed the conversion electrons and allowed gating only on higher energy electrons from beta decay and thereby excluded most beta-decay electrons from the electron singles spectrum.

B. Experimental results

The proposed level scheme for ^{143}La populated in the decay of ^{143}Ba is shown in Fig. 1. Levels and gamma rays were placed to an energy of 2540 keV. The energy values, intensities, and placements for the gamma transitions observed in this experiment are given in Table I. The gamma rays present in the major coincidence gates are shown in Table II. The energy values were determined from spectra accumulated by counting the gamma rays from ^{143}Ba decay simultaneously with ^{152}Eu and ^{228}Th standards. In addition, precise energy values for a number of gamma rays in this chain have been determined by Borner *et al.*[30] Our values for the gamma rays at 211.475(7), 291.724(17), and 397.676(8) keV are in excellent agreement with those of Borner *et al.* and their values have been reported in Table I. But, the gamma transitions that they identify at 176.349(10), 178.984(12), 181.119(6), 207.071(32), and 431.384(13) keV, and assign to ^{143}Ba decay are ~0.5 keV from the values we list in Table I. The energy of the 29.85-keV transition as determined from their 211-181 and 207-178 differences are not the same and not in agreement with a number of the differences that we observe. It is most likely that those five gamma rays observed by Borner *et al.* should be assigned to the decay of other nuclides.

The ground-state beta branch from ^{143}Ba was calculated assuming an absolute intensity of 24.9±2.9 % for the 211-keV gamma ray, as reported by Sohnius *et al.*,[25] and the log*ft* values were calculated assuming a Q_β value of 4240±50 keV as reported by Schussler *et al.*[17] It was possible to account for 92.5% of the feeding of the ground state by adding up the gamma-ray intensity into the ground and first excited states. It is quite likely that there are additional weak gamma rays that have not been observed and that feed into the lower-lying levels. Thus, the beta intensity shown for the ground state is an upper limit. Possible beta population for the remainder of the levels was calculated by computing the difference between gamma decay from a level and gamma decay to that level. In view of the possibility of additional beta feeding from higher energy transitions that have not been observed or resolved, values less than 2% have not been shown in Fig. 1 nor values where the computed beta population was within 2 σ of zero.

The gamma-gamma angular correlation measurements were limited to cascades that involve one $E1$ transition. Because $A_{44}=0$ for such cascades, it was necessary to take data only at 90° and 180°. The results of the gamma-gamma angular correlation measurements are given in Table III. The data were fit to the Legendre function to extract that A_{22} value:

$$W(\theta)=A_0[1+A_{22}P_2(\cos\theta)] .$$

With four detectors, four points at 90° and two at 180° were accumulated. Solid angle corrections were made using a procedure described by Camp and Van Lehn.[31]

The internal conversion coefficients deduced from the conversion electron measurements are given in Table IV. The α_K and α_L coefficients are listed with the most likely multipolarities of the transitions. All values were normalized to the *K* coefficient of the 211-keV gamma ray measured by Schussler *et al.*[17] The α_K values for $M1$ and $E2$ conversion are nearly identical at 211 keV.

C. The level scheme of ^{143}La

With our newly identified gamma rays and coincidence relationships, many new levels have been proposed for ^{143}La. The changes are largely concentrated in the energy range between 1200 and 1800 keV where only the levels at 1291 and 1407 keV had been previously placed. Only three new levels at 462, 884, and 955 keV have been proposed below 1 MeV.

The new level at 462 keV is depopulated by new transitions at 250 and 432 keV, and by the 462-keV gamma ray previously reported to depopulate a level at 1871 keV. The assignment was made by observing a strong coincidence between the 250- and 211-keV gamma rays in their gated spectra. Gates on all three depopulating gam-

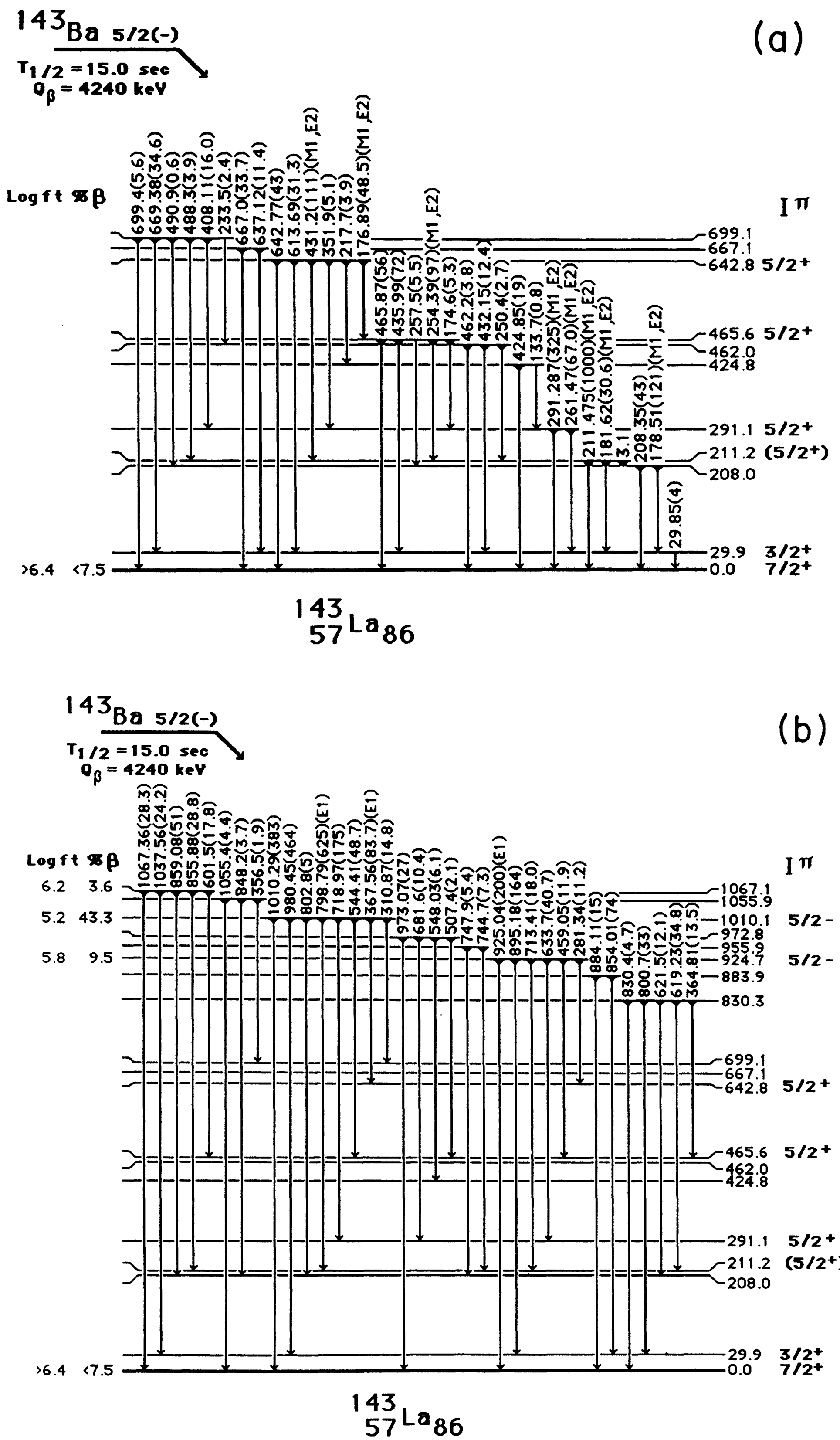

FIG. 1. (a) The levels of ^{143}La populated in the decay of ^{143}Ba (0–700 keV). (b) The levels of ^{143}La populated in the decay of ^{143}Ba (800–1100 keV). (c) The levels of ^{143}La populated in the decay of ^{143}Ba (1100–1420 keV). (d) The levels of ^{143}La populated in the decay of ^{143}Ba (1420–1800 keV). (e) The levels of ^{143}La populated in the decay of ^{143}Ba (1800–2325 keV). (f) The levels of ^{143}La populated in the decay of ^{143}Ba (2325–2540 keV).

ma rays showed a transition at 840 keV indicating that it feeds the 462-keV level. The level at 884 keV was deduced from gates on the 854 and 884-keV gamma rays. The 884-keV transition was found to be a doublet with one member populating the 1407-keV level and the other in strong coincidence with the 685-keV gamma ray. A gated spectrum on the 685-keV transition showed lines at both 854 and 884 keV, but the latter two were not found to be in coincidence. From these data it was evident that they either populated or depopulated the same level. The 30-keV difference in energy strongly suggests that they decay to the ground state and the 30-keV levels.

The level at 955 keV depopulates by gamma rays at 745 and 747 keV. The latter was observed in spectra gated on the 178- and 208-keV transitions, while the 745-keV gamma ray was seen in the 211- and 181-keV gates. The gamma rays were assigned to a single level when it was found they were not in coincidence. The other new levels are supported by the observed coincidences shown in Table II.

Two of three levels tentatively proposed by Schussler *et al.*[17] were confirmed in this scheme. The 667-keV level was established by data from gates placed on the depopulating 637- and 666-keV gamma rays. The 972-keV level was found to decay by four transitions, two of which were previously unobserved.

Evidence was not found to support the existence of an 1871-keV level. The proposed 462-keV depopulating gamma ray was determined to be a ground-state transition, and the 421- and 1405-keV gamma rays were not placed in the current scheme. The two are not in coincidence with each other or with the 462-keV transition.

The presence of a 3.0-keV transition between the levels at 211 and 208 keV is implied by the appearance of gamma rays that populate the 211-keV level in the coincidence gate on the 208-keV gamma ray as shown in Fig. 2. A portion of the ^{143}La singles spectrum from 160 to 270 keV is shown in Fig. 3 where the 208- and 211-keV gamma rays are shown to be completely resolved. The intensity value listed in Table I was computed from the

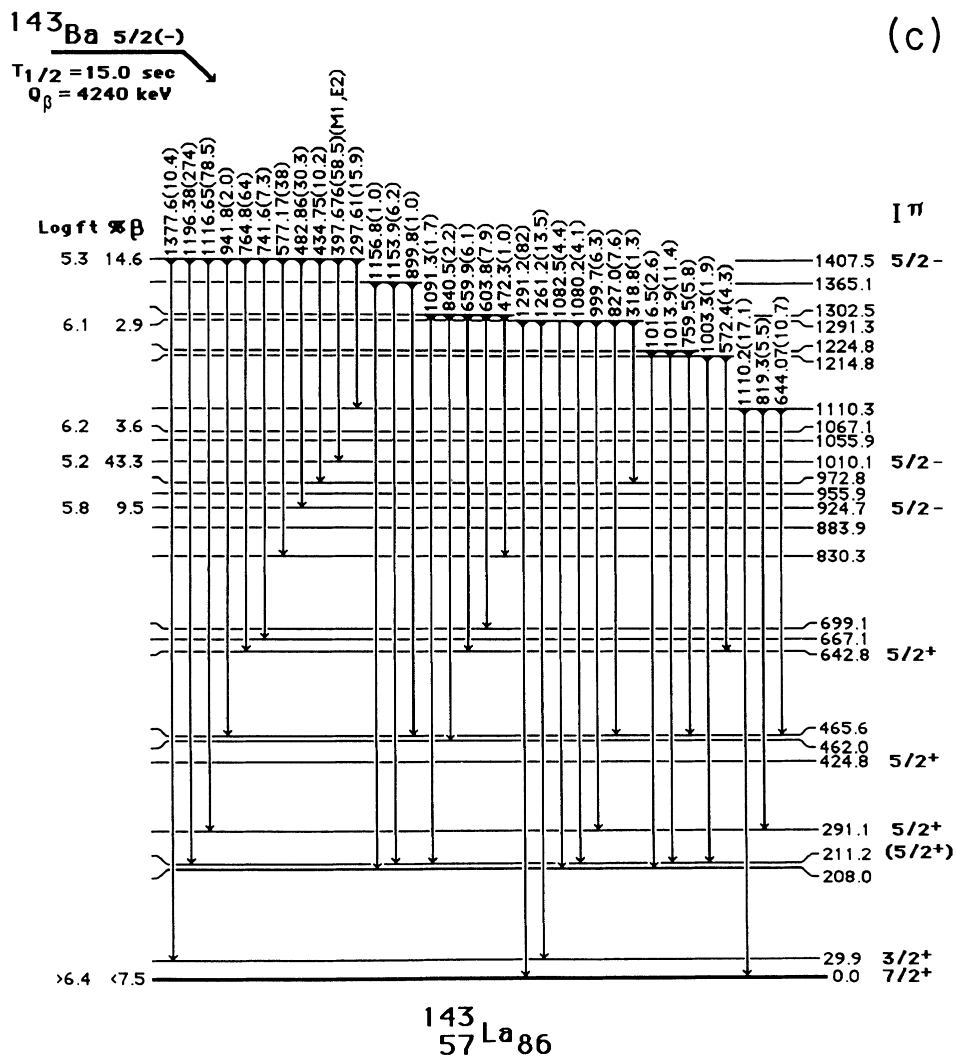

FIG. 1. (*Continued*).

intensities of gamma rays that populate the 211-keV level that are found in the gate on the 178- and 208-keV gamma rays.

D. Spin and parity assignments in ^{143}La

A $\frac{7}{2}^+$ ground-state spin and parity for ^{143}La is suggested by the systematics of the lighter odd-mass lanthanum isotopes and the $N=86$ isotones ^{145}Pr and ^{147}Pm where $l=4$ values have been observed in transfer reactions.[32–37] A $\frac{7}{2}$ assignment has also been established[8,9] for isotonic ^{141}Cs. Substantial evidence is also found in comparing the levels fed in ^{143}Ce from the beta decay of ^{143}La to the levels populated in neutron capture of ^{142}Ce to levels of ^{143}Ce.[36] The beta decay populates a level in ^{143}Ce that is assigned spin and parity of $\frac{9}{2}^-$ in transfer reactions but does not populate levels assigned spin and parity of $\frac{1}{2}^-$ and $\frac{3}{2}^-$ in capture-gamma studies. A spin of $\frac{5}{2}^-$ has been established for the ^{143}Ba parent.[38]

Absolute intensity values for the major gamma rays reported by Sohnius *et al.*[25] were compared with values observed for the $A=143$ chain saturated through the decay of 14-min ^{143}La. The saturation values of gamma rays in ^{143}La relative to gamma rays in the ^{143}Ce daughter, and the reported ratios of the most intense lines were found to be in agreement. An upper limit for the ground-state

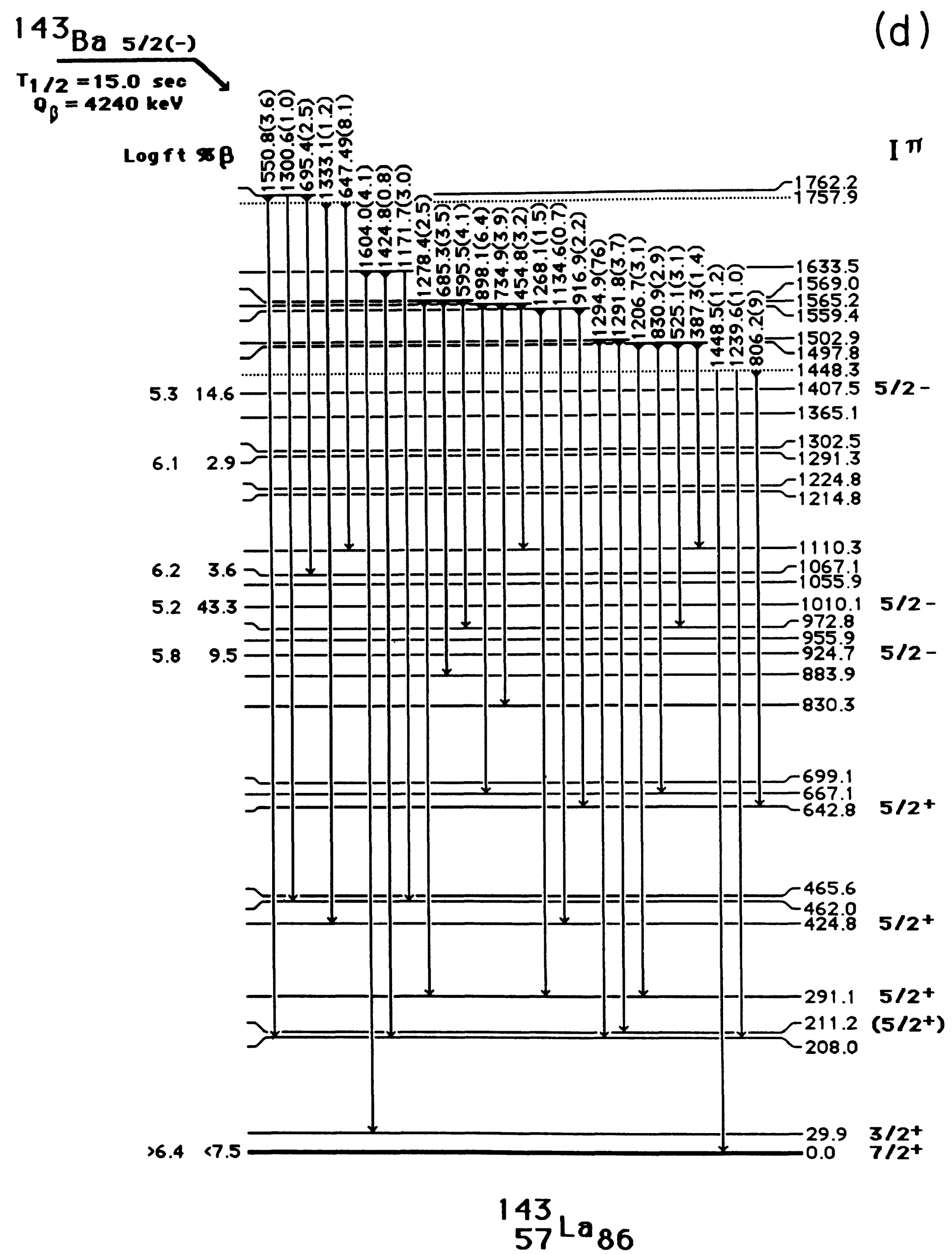

FIG. 1. (*Continued*).

beta feeding of the present scheme was determined to be 7.5±10 %, giving a lower limit for the ground-state log*ft* of 6.2. The large uncertainty arises from the large uncertainty in the value of the absolute intensity reported by Sohnius *et al.* The log*ft* is toward the lower end of the range expected for a first-forbidden nonunique beta transition, and is consistent with the $\frac{5}{2}^-$ spin and parity assignment for ^{143}Ba and a $\frac{7}{2}^+$ assignment for the ground state of ^{143}La.

Conversion-electron intensities for ^{143}La were measured primarily to determine the multipolarities of the gamma rays that depopulate the strongly beta-fed levels at 925, 1010, and 1407 keV. The results, shown in Table IV, indicate $E1$ multipolarity for major gamma rays depopulating these levels and confirm the negative parity assigned to the three levels and also indicate that levels at 30, 208, 211, 291, 466, and 642 keV have positive parities. The multipolarities of transitions from negative-parity states to lower-lying positive parity states are easily determined by their small $E1$ conversion coefficients. The fact that no K line was observed for the 925-keV transition implies that it has an $E1$ multipolarity. If it were otherwise, its peak area would have approached the size of the K line of the 799-keV transition, which was easily ob-

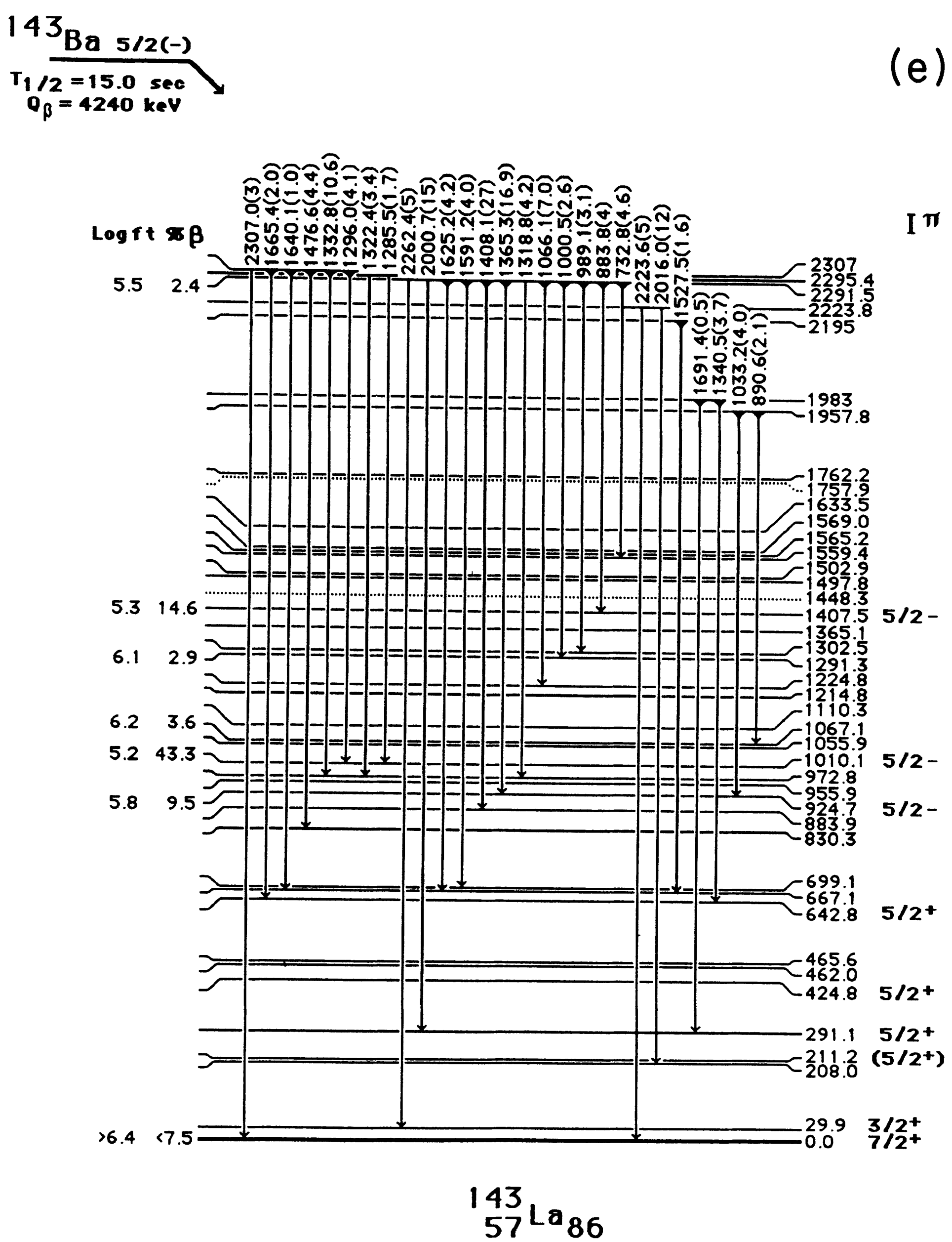

FIG. 1. (*Continued*).

served. The present work and the studies by Rapaport and Gayer[26] and by Schussler *et al.*[17] all support an $M1/E2$ multipolarity for the 397-keV gamma ray. This transition populates the level at 1010 keV from the 1407-keV level and this measurement requires those levels to have the same parity. The conversion coefficient of the 799-keV gamma ray was measured in this study to be consistent with an $E1$ multipolarity. Rapaport and Gayer did not observe K conversion electrons for this transition and concluded from its upper limit that it was an $E1$ transition.

The 30-keV first excited level of ^{143}La does not appear to be populated directly in beta decay and decays by a highly converted 30-keV gamma-ray transition. Theoretical total conversion coefficient values are 5.6 for a pure $M1$ transition and 250 for a pure $E2$ transition.[39] The uncertainty in the total decay intensity reported is dependent upon the uncertainty of the 30-keV gamma-ray peak

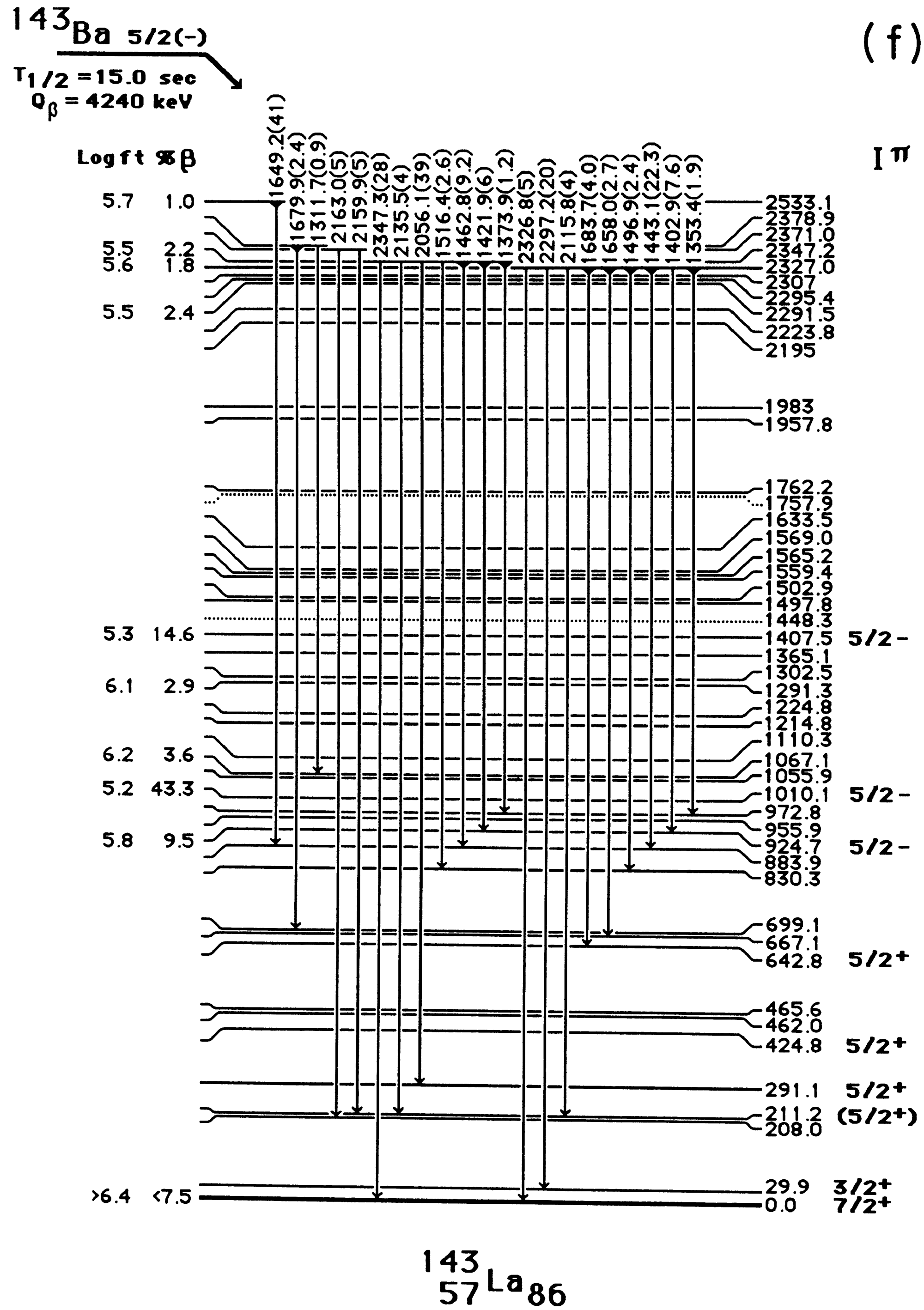

FIG. 1. (*Continued*).

TABLE I. Gamma-ray energies and intensities for ^{143} decay to ^{143}La.

E (kEV)[a]	*I* (total)[b]	*I* (gamma)[b]	From	To
3.1(1)	47(12)		211	208
29.85(5)	1230(100)[c]	4(1)	30	0
133.7(1)	1.1(3)	0.8(2)	425	291
174.6(1)	6.5(2)	5.3(2)	466	291
176.89(2)	58.8(6)	48.5(5)	643	466
178.51(2)	146(2)	121(1)	208	30
181.62(3)	36.6(4)	30.6(3)	211	30
208.35(2)	49(1)	43(1)	208	0
211.475(7)	1140(10)	1000	211	0
217.7(1)	4.4(3)	3.9(2)	643	425
233.5(1)	2.4(2)	2.4(2)	699	466
250.4(1)	3.0(2)	2.7(2)	462	211
254.39(2)	105(1)	97(1)	466	211
257.5(1)	5.9(2)	5.5(2)	466	208
261.47(3)	72.4(7)	67.0(7)	291	30
281.34(5)	12.0(3)	11.2(2)	925	643
291.287(20)	345(3)	325(3)	291	0
297.61(6)	16.1(2)	15.9(2)	1408	1110
310.87(6)	15.0(3)	14.8(3)	1010	699
318.8(1)	1.4(2)	1.3(2)	1291	973
351.9(1)	5.3(4)	5.1(4)	643	291
356.5(1)	1.9(2)	1.9(2)	1056	699
364.81(7)	14.0(5)	13.5(5)	830	466
367.56(3)	84.5(8)	83.7(8)	1010	643
387.3(1)	1.4(4)	1.4(4)	1498	1110
397.676(8)	60.1(6)	58.5(6)	1408	1010
408.11(5)	16.5(4)	16.0(4)	699	291
421.4(1)	1.9(9)	1.8(8)	unplaced	
424.85(5)	19(1)	19(1)	425	0
431.20(4)	113(4)	111(4)	643	211
432.15(5)	12.6(8)	12.4(7)	462	30
434.75(7)	10.2(6)	10.2(6)	1408	973
435.99(3)	73(3)	72(3)	466	30
454.8(1)	3.2(7)	3.2(7)	1565	1110
459.05(8)	12.1(8)	11.9(7)	925	466
462.2(1)	3.8(2)	3.8(2)	462	0
465.87(3)	57(1)	56(1)	466	0
472.3(1)	1.1(3)	1.0(3)	1303	830
482.86(4)	30.4(6)	30.3(6)	1408	925
488.3(1)	4.0(3)	3.9(3)	699	211
490.9(3)	0.6(2)	0.6(2)	699	208
507.4(1)	2.1(5)	2.1(5)	973	466
525.1(1)	3.2(5)	3.1(5)	1498	973
544.41(4)	48.8(6)	48.7(6)	1010	466
548.0(2)	6.2(2)	6.1(2)	973	425
558.9(1)	2.4(5)	2.4(5)	unplaced	
572.4(1)	4.3(7)	4.3(7)	1215	643
577.17(4)	38(1)	38(1)	1408	830
595.5(1)	4.1(3)	4.1(3)	1569	973
601.5(1)	18.0(6)	17.8(6)	1067	466
603.8(1)	8.0(3)	7.9(3)	1303	699
608.2(3)	0.9(3)	0.9(3)	unplaced	
613.69(4)	31.3(9)	31.3(9)	643	30
619.23(4)	35.2(9)	34.8(9)	830	211
621.5(1)	12.2(8)	12.1(8)	830	208
633.70(3)	41.1(5)	40.7(5)	925	291
637.12(8)	11.4(8)	11.4(8)	667	30
642.77(5)	43(2)	43(2)	643	0
644.07(9)	10.8(6)	10.7(6)	1110	463
647.49(9)	8.2(3)	8.1(3)	1758	1110
649.9(2)	2.1(8)	2.1(8)	unplaced	
659.9(2)	6.2(5)	6.1(5)	1303	643
667.00(4)	34.0(4)	33.7(4)	667	0
669.38(4)	34.8(4)	34.6(4)	669	30
681.6(2)	10.5(5)	10.4(5)	973	291
685.3(2)	3.5(2)	3.5(2)	1569	884
695.4(2)	2.5(3)	2.5(3)	1762	1067
699.4(2)	5.6(6)	5.6(6)	699	0
713.41(6)	18.1(9)	18.0(9)	925	211
718.97(2)	176(2)	175(2)	1010	291
723.2(2)	2.8(9)	2.8(9)	unplaced	
732.8(2)	4.6(3)	4.6(3)	2292	1559
734.9(2)	4.0(2)	3.9(2)	1565	830
739.1(2)	5.9(7)	5.8(7)	unplaced	
741.6(2)	7.3(3)	7.3(3)	1408	667
744.7(2)	7.4(8)	7.3(8)	956	211
747.9(2)	5.4(7)	5.4(7)	956	208
759.5(2)	5.9(4)	5.8(4)	1225	466
764.8(1)	64(1)	64(1)	1408	643
782.91(3)	3.7(5)	3.7(5)	unplaced	
798.79(2)	625(13)	625(13)	1010	211
800.7(2)	33(7)	33(7)	830	30
802.8(2)	5(1)	5(1)	1010	208
806.2(2)	9(2)	9(2)	1448	643
819.3(3)	5.5(3)	5.5(3)	1110	291
827.0(4)	7.6(4)	7.6(4)	1291	466
830.4(4)	4.7(2)	4.7(2)	830	0
830.9(4)	2.9(2)	2.9(2)	1498	667
834.8(4)	3.3(3)	3.3(3)	unplaced	
840.5(4)	2.2(3)	2.2(3)	1303	462
848.2(4)	3.7(4)	3.7(4)	1056	208
854.01(4)	74(1)	74(1)	884	30
855.88(6)	28.8(9)	28.8(9)	1067	211
859.08(4)	51(3)	51(3)	1067	208
884.11(6)	15(3)	15(3)	884	0
883.8(5)	4(2)	4(2)	2292	1408
890.6(4)	2.1(5)	2.1(5)	1958	1067
895.18(3)	164(1)	164(1)	925	30
898.1(3)	6.4(3)	6.4(3)	1565	667
899.8(5)	1.0(3)	1.0(3)	1365	466
916.9(3)	2.2(6)	2.2(6)	1559	643
925.04(3)	200(2)	200(2)	925	0
930.4(5)	0.9(2)	0.9(2)	unplaced	
941.8(2)	2.0(3)	2.0(3)	1408	466
952.8(3)	1.6(5)	1.6(5)	unplaced	
959.0(3)	1.6(5)	1.6(5)	unplaced	
973.07(5)	27(1)	27(1)	973	0
980.45(2)	464(5)	464(5)	1010	30
989.1(3)	3.1(5)	3.1(5)	2292	1303
999.7(3)	6.3(7)	6.3(7)	1291	291
1000.5(4)	2.6(4)	2.6(4)	2292	1291
1003.3(4)	1.9(7)	1.9(7)	1215	211
1010.29(2)	383(8)	383(8)	1010	0
1013.9(1)	11.4(7)	11.4(7)	1225	211
1016.5(4)	2.6(2)	2.6(2)	1225	208
1033.2(4)	4.0(2)	4.0(2)	1958	925
1037.56(7)	24.2(6)	24.2(6)	1067	30
1055.4(4)	4.4(4)	4.4(4)	1056	0
1066.1(5)	7.0(3)	7.0(3)	2292	1225
1067.36(5)	28.3(3)	28.3(3)	1067	0

TABLE I. *(Continued)*.

E (kEV)[a]	I (total)[b]	I (gamma)[b]	From	To	E (kEV)[a]	I (total)[b]	I (gamma)[b]	From	To
1080.2(4)	4.1(3)	4.1(3)	1291	211	1456.7(5)	2.8(2)	2.8(2)	unplaced	
1082.5(4)	4.4(3)	4.4(3)	1291	208	1462.8(3)	9.2(3)	9.2(3)	2347	884
1091.3(4)	1.7(10)	1.7(10)	1303	211	1476.6(3)	4.4(3)	4.4(3)	2307	830
1110.2(1)	17.1(2)	17.1(2)	1110	0	1484.6(5)	1.0(2)	1.0(2)	unplaced	
1116.65(3)	78.5(6)	78.5(6)	1408	291	1496.9(5)	2.4(2)	2.4(2)	2327	830
1134.6(5)	0.7(2)	0.7(2)	1559	425	1516.4(5)	2.6(2)	2.6(2)	2347	830
1153.9(3)	6.2(6)	6.2(6)	1365	211	1527.5(5)	1.6(2)	1.6(2)	2195	667
1156.8(5)	1.0(2)	1.0(2)	1365	208	1550.8(5)	3.6(2)	3.6(2)	1762	211
1171.7(5)	3.0(6)	3.0(6)	1634	462	1591.2(5)	4.0(3)	4.0(3)	2292	699
1196.38(6)	274(3)	274(3)	1408	211	1604(1)	4.1(2)	4.1(2)	1634	30
1206.7(4)	3.1(7)	3.1(7)	1498	291	1625.2(5)	4.2(3)	4.2(3)	2292	667
1239.6(4)	1.0(4)	1.0(4)	1448	208	1640.1(4)	1.0(2)	1.0(2)	2307	667
1261.2(2)	13.5(3)	13.5(3)	1291	30	1645.1(3)	7(1)	7(1)	unplaced	
1268.1(4)	1.5(3)	1.5(3)	1559	291	1649.19(1)	41(2)	41(2)	2533	884
1278.4(4)	2.5(2)	2.5(2)	1569	291	1658.0(4)	2.7(2)	2.7(2)	2327	667
1285.5(4)	1.7(2)	1.7(2)	2295	1010	1665.4(3)	2.0(2)	2.0(2)	2307	643
1291.2(1)	82(4)	82(4)	1291	0	1679.9(3)	2.4(2)	2.4(2)	2379	699
1291.8(4)	3.7(2)	3.7(2)	1503	211	1683.7(3)	4.0(3)	4.0(3)	2327	643
1294.9(2)	76(4)	76(4)	1503	208	1691.4(5)	0.5(2)	0.5(2)	1983	291
1296.0(4)	4.1(2)	4.1(2)	2307	1010	2000.7(1)	15(1)	15(1)	2291	291
1300.6(5)	1.0(3)	1.0(3)	1762	462	2016(2)	12(1)	12(1)	2224	208
1311.7(5)	0.9(2)	0.9(2)	2379	1067	2056.1(1)	39(2)	39(2)	2347	291
1318.8(3)	4.2(3)	4.2(3)	2292	973	2115.8(3)	4(1)	4(1)	2327	211
1322.4(4)	3.4(2)	3.4(2)	2295	973	2135.5(3)	4(1)	4(1)	2347	211
1332.8(3)	10.6(7)	10.6(7)	2307	973	2159.9(3)	5(1)	5(1)	2371	211
1333.1(4)	1.2(1)	1.2(1)	1758	425	2163.0(3)	5(1)	5(1)	2371	208
1340.5(4)	3.7(3)	3.7(3)	1983	643	2211.2(4)	3(1)	3(1)	unplaced	
1353.4(5)	1.9(4)	1.9(4)	2327	973	2223.6(3)	5(1)	5(1)	2224	0
1365.3(4)	16.9(3)	16.9(3)	2292	925	2258.8(6)	2(1)	2(1)	unplaced	
1373.9(4)	1.2(2)	1.2(2)	2347	973	2262.4(3)	5(1)	5(1)	2292	30
1377.6(4)	10.4(5)	10.4(5)	1408	30	2277.6(2)	8(1)	8(1)	unplaced	
1402.9(4)	7.6(3)	7.6(3)	2327	925	2297.2(1)	20(2)	20(2)	2327	30
1408.1(2)	27(1)	27(1)	2292	884	2307.0(5)	3(1)	3(1)	2307	0
1421.9(2)	6(1)	6(1)	2347	925	2326.8(3)	5(1)	5(1)	2327	0
1424.8(5)	0.8(2)	0.8(2)	1634	208	2347.3(1)	28(2)	28(2)	2347	0
1443.1(2)	22.3(3)	22.3(3)	2327	884	2386.9(2)	9(1)	9(1)	unplaced	
1448.5(5)	1.2(2)	1.2(2)	1448	0	2499.8(4)	2.4(6)	2.4(6)	unplaced	

[a]The uncertainties in the energy values are given in parentheses. The values given to three significant figures are taken from Borner *et al.* (Ref. 30).

[b]The uncertainty in the intensity is given in parentheses.

[c]The total intensity of the 29.9-keV transition is given as the sum of the intensities of transitions that populate the level. It is a lower limit as it excludes possible direct beta population and possible population from high-energy unidentified and unplaced transitions.

area and the detector, efficiency determination. A portion of a low-energy spectrum of ^{143}Ba decay collected with a small planar Ge detector, is shown in Fig. 4. The 30-keV gamma ray was found to have a relative intensity of 4 ± 1 and a total transition intensity of 1000 ± 250 for a pure $E2$ transition. The low-energy cutoff of the Si(Li) detector in the conversion-electron experiment did not allow us to obtain a conversion coefficient. But, the intensity of the gamma population of this level, which totals 1230 intensity units, requires the depopulating gamma ray to be a pure $E2$ transition. Schussler *et al.*[17] assigned $E2$ multipolarity to this transition and a $\frac{3}{2}^+$ spin to the 30-keV level on the basis of an L/M conversion ratio and an L-line conversion coefficient measurement. The L/M ratio reported by Rapaport and Gayer[26] supports the data of this experiment.

Note that the spin and parity assignment are dependent upon the assumption that if $M1$ competition were possible, it would be observed. Since no $M1$ competition is observed, it must be assumed that the 30-keV level differs in spin by at least 2 units of angular momentum from the $\frac{7}{2}^+$ ground state, leaving the choices as $\frac{3}{2}^+$ or $\frac{11}{2}^+$. Such an assumption is less easily justified for higher-energy transitions where there are several mechanisms that can suppress the $M1$ branch and enhance the $E2$ branch. But, at low energy and near the ground state, these configuration admixtures are not generally present. Moreover, owing to the E^5 energy dependence of the $E2$ transition rate versus the E^3 dependence of the $M1$ part, an enormous suppression would be required at 30 keV to

TABLE II. Coincidences observed in the decay of ^{143}Ba to levels of ^{143}La.

Gate	Gamma rays observed in the gate (energies in keV)									
174	177	254	261	291	367	544	835	942	1497		
177	174	178	191	211	254	257	281	291	367	397	436
	466	719	765	806	835	900	917	1340	1649	1683	
178	177	254	257	281	397	431	435	459	491	544	557
	602	620	622	748	783	799	806	822	859	1016	1113
	1157	1196	1235	1295	1425	1649					
208	254	257	281	491	577	622	748	799	803	848	859
	1249	1381	1425								
211	177	250	254	297	310	364	367	397	431	459	515
	544	577	602	620	713	745	758	765	799	819	856
	844	942	1003	1014	1055	1066	1080	1091	1137	1154	1196
	1239	1285	1291	1367	1443	1477	1527	1550	1649	1683	
254	177	178	182	208	211	233	297	364	367	397	459
	466	507	544	577	602	644	765	827	900	943	1649
291	134	174	177	297	310	327	331	351	367	397	408
	435	483	634	682	689	719	748	819	884	900	1000
	1034	1117	1130	1207	1268	1278	1337	1367	1543	1649	1680
	1691										
367	177	182	211	218	254	291	351	397	407	424	431
	436	466	577	614	644	669	830				
397	177	178	181	211	254	261	291	367	431	436	466
	491	544	719	799	981	1010					
425	218	297	367	435	548	685	739	1135	1319	1333	1649
431	177	182	211	367	368	383	397	577	765	840	917
	980	1172	1306	1389	1589	1649	1683				
577	177	208	211	254	365	367	431	435	466	620	669
	799	830	1003	1196							
619	211	472	577	733	803	843	1154	1477	1497	1516	
634	261	291	346	483	1033	1367	1403	1422			
643	211	297	367	436	459	466	647	664	765	917	1340
	1649										
667	548	604	742	831	900	1527	1625	1658			
685	297	425	643								
748	178	208	799	835	1080						
799	178	182	208	211	397	577	650				
854	155	157	408	466	685	879	1066	1086	1408	1443	1463
	1647										
859	150	178	208	281	1312						
942	174	178	182	208	211	254	257	435	466	821	1196
973	319	435	1010	1319	1333	1373	1393	1448	1591		
1111	297	387	455								
1443	854	884									
1453	854	884									

TABLE III. Angular correlation coefficients for ^{143}La cascades.

Cascade[a]	$A22$	Cascade	$A22$
254-211	-0.099 ± 0.016	367-431[b]	-0.13 ± 0.02
431-211[b]	-0.10 ± 0.02	544-435[b]	-0.33 ± 0.03
799-211	-0.01 ± 0.02	177-435[b]	0.04 ± 0.04
1196-211	-0.02 ± 0.02	254-544	0.08 ± 0.04
713-211	0.06 ± 0.06	261-719	-0.14 ± 0.03
856-211	-0.12 ± 0.04	291-719	-0.22 ± 0.04
719-291	-0.23 ± 0.04	182-799	0.08 ± 0.04
1117-291	-0.20 ± 0.04	211-799	-0.013 ± 0.009
799-397	0.01 ± 0.03	397-799	-0.02 ± 0.03
211-431[b]	0.03 ± 0.01		

[a]Energies are given in keV. The gate is on the second gamma ray.
[b]Note the presence of the 431-435 keV doublet.

an enormous suppression would be required at 30 keV to quench the $M1$ admixture between two states that differ by only 1 unit of angular momentum. The $\frac{11}{2}^+$ possibility is easily ruled out by the numerous direct gamma-ray transitions from levels strongly populated in direct beta decay from the $\frac{5}{2}^-$ ^{143}Ba.

Spin and parity assignments for several levels that are established as having negative parity by either strong beta feeding or decay by $E1$ transitions are quite straightforward. The parity of the 1010-keV level is established as negative by the strong beta feeding that indicates an allowed beta transition from the $\frac{5}{2}^-$ ground state of ^{143}Ba and by the 799-keV $E1$ transition to the positive-parity level at 211 keV. Gamma-ray branches with $E1$ multipolarity of approximately equal intensity to the $\frac{7}{2}^+$ ground state and $\frac{3}{2}^+$ first excited level are possible only for a spin of $\frac{5}{2}$. The $E1$ multipolarity of the 925-keV transition also establishes negative parity for the 925-keV level and nearly equal branching to the two lowest-lying levels requires a spin of $\frac{5}{2}$. Negative parity for the 1407-keV level is also established by strong beta feeding and the $M1/E2$ character of the 397-keV transition to the $\frac{5}{2}^-$ level at 1010-keV. The absence of a transition to the $\frac{7}{2}^+$ ground state allows, but does not require a spin of $\frac{3}{2}$. Relatively strong beta feeding to levels at 1067 and 1291 keV suggests negative parity, and, as both of these levels feed the two lowest levels, their spins in that case would be $\frac{5}{2}$.

Except for the level at 424 keV, all 11 levels between 200 and 900 populate both the $\frac{7}{2}^+$ ground and first excited $\frac{3}{2}^+$ levels with intensities of the same order of magnitude. Thus, these levels are restricted to spins of $\frac{3}{2}$, $\frac{5}{2}$, and $\frac{7}{2}$ with positive parity and only $\frac{5}{2}$ if any of them have negative parity. Although the absence of a gamma-ray branch from the 424-keV level to the $\frac{3}{2}^+$ level could allow $\frac{9}{2}^+$ spin and parity for that level, the feeding of that level from the $\frac{5}{2}^-$ level at 1010 keV eliminates this possibility.

As was noted in earlier angular correlation studies[10,12] of levels in ^{139}Cs and ^{141}La, it is generally not possible to make explicit spin and parity assignments in odd-mass nuclides based on angular correlation data. This difficulty arises from the fact that there are five variables associated with a gamma-gamma cascade, three spin values and two mixing values, and only one (A_{22}) or two (A_{22} and A_{44}) quantities determined from the data. Where $E1$ transitions can be identified, however, the $M2$ mixing value is quite likely near zero, and thus A_{44} is likely near zero. If one or two spin values can be determined from other data, then angular correlation results can be used to sharply restrict the possible spin and mixing values for levels and transitions involved. The upper limits for beta feeding to the levels in this energy region is so weak that no additional restrictions can be imposed on the spins and parities from beta decay.

The strongest gamma-gamma cascade in the decay to this nucleus is the 799-211-keV cascade from the 1010-keV level. It was measured with gates on both gamma rays, and the two angular correlation coefficients are in good agreement. The uncertainties obtained from the fits appear quite large compared to the coefficients. But con-

TABLE IV. Conversion coefficients for ^{143}La.

E (keV) ^{143}La	α_K α_L	Theoretical coefficients[a] $E1$	$E2$	$M1$	Probable Multipolarity
211	0.11 norm	0.025	0.11	0.12	$M1,E2$
	0.014 ± 0.003	0.0032	0.026	0.016	
254	0.061 ± 0.006	0.015	0.060	0.070	$M1,E2$
261	0.047 ± 0.005	0.014	0.056	0.065	$M1,E2$
291	0.039 ± 0.002	0.011	0.040	0.049	$M1,E2$
	0.0079 ± 0.0010	0.0014	0.0078	0.0066	
367	0.0077 ± 0.0023	0.0062	0.021	0.027	$E1$
397	0.022 ± 0.004	0.0051	0.016	0.022	$M1,E2$
431[b]	0.012 ± 0.002	0.0042	0.013	0.018	$E2,M1$
	0.0027 ± 0.0011	0.0005	0.0021	0.0023	
799	0.0009 ± 0.0003	0.0011	0.0026	0.0040	$E1$
925	not observed	0.008	0.0019	0.0028	$E1$

[a]The theoretical values are from Ref. 39.
[b]Doublet gamma-ray peak.

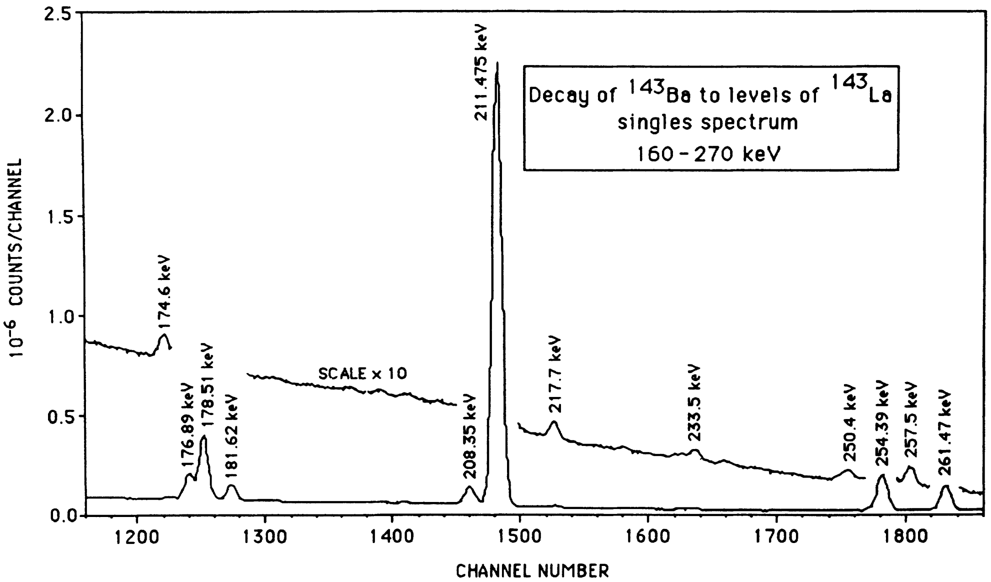

FIG. 2. Gamma-ray singles spectrum of ^{143}Ba decay in the 160–270 keV energy range.

sidering that the coefficients themselves are quite small and the fits are good, it is evident that there is little change in the angular intensity. The coefficients are consistent with a $\frac{5}{2}(1)\frac{5}{2}(1,2)\frac{7}{2}$ cascade, which has an A_{22} range of -0.38 to $+0.42$. A $\frac{5}{2}(1)\frac{3}{2}(2)\frac{7}{2}$ cascade has a single theoretical A_{22} value of -0.014, identical to the measured values for this cascade. A $\frac{3}{2}^+$ assignment is supported by the gamma feedings from higher levels. With the exception of the 291-keV level, every level in the scheme that feeds the 30-keV state also feeds the 211-keV level. Although the calculated α_K values for both $M1$ and $E2$ transitions are nearly identical, the α_L values are quite different and the value we measure, and the value reported by Rapaport and Gayer,[26] both indicate nearly pure $M1$ multipolarity. The portion of the conversion electron spectrum containing the 211-keV L is shown in Fig. 5. The A_{22} value for a $\frac{5}{2}(1)\frac{5}{2}(1)\frac{7}{2}$ cascade is -0.057. The δ value of the 211-keV transition for the range of A_{22} values within one sigma is 0.07 ± 0.03. The angular intensity values for the 799-181-keV cascade were obtained by gating only on the 799-keV gamma ray

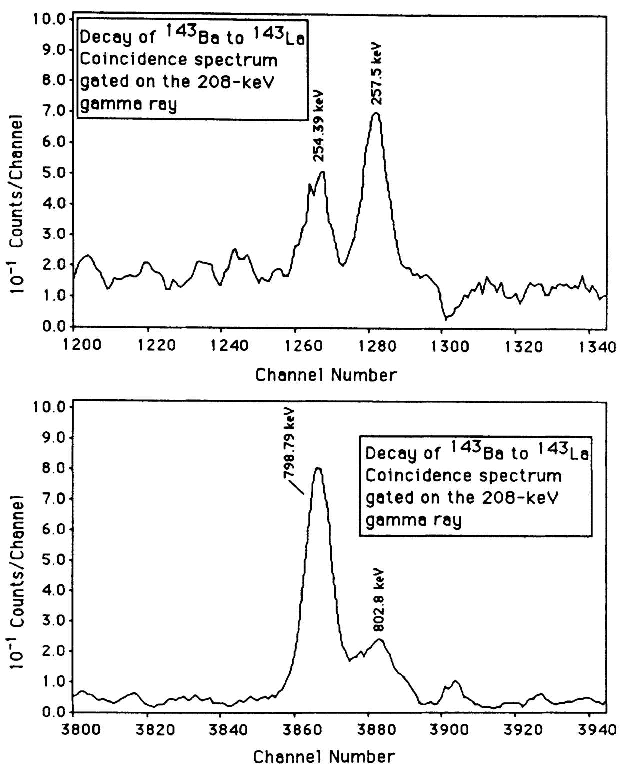

FIG. 3. Portions of the gamma-ray coincidence spectrum gated on the 208-keV gamma ray.

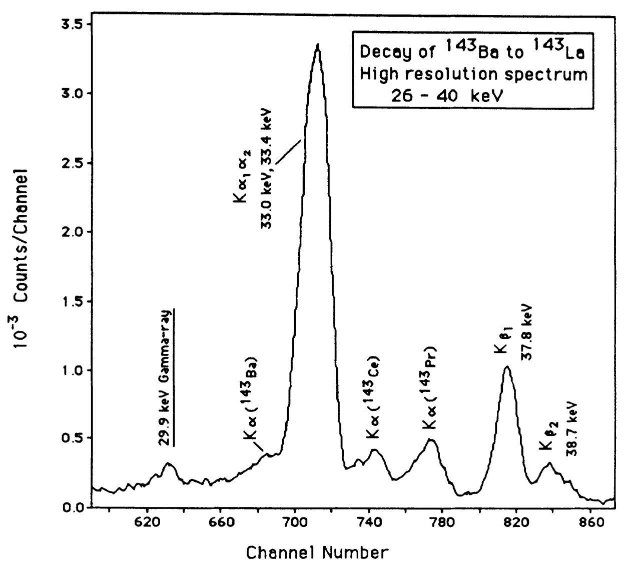

FIG. 4. Gamma-ray singles spectrum in the energy range from 28–40 keV taken with a small planar detector.

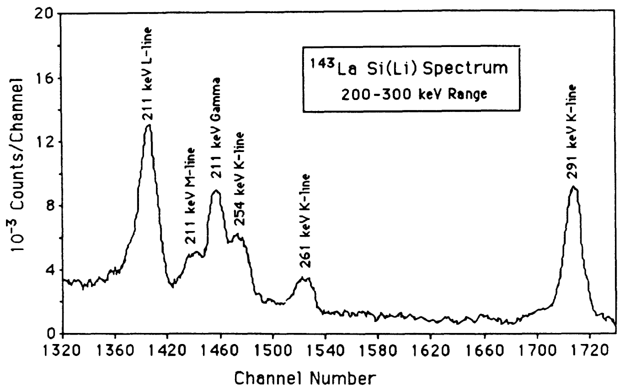

FIG. 5. Conversion-electron spectrum between 200 and 300 keV.

only. The coefficient of $+0.08(4)$ for this cascade is not consistent with a $\frac{5}{2}(1)\frac{7}{2}(2)\frac{3}{2}$ sequence whose A_{22} is fixed at -0.156 and can therefore be used to rule out spin and parity of $\frac{7}{2}^+$ for the 211-keV level. A spin and parity of $\frac{5}{2}^+$ are consistent with all of the data, but $\frac{3}{2}^+$ is ruled out only on the basis of the L conversion coefficient. For this reason, the assignment of $\frac{5}{2}^+$ is shown in parentheses in Fig. 1.

The 719-291-keV cascade from the 1010-keV level through the 291-keV level shows a large anisotropy. The A_{22} coefficients of the two fits are equal within their uncertainties. The conversion coefficients for both K and L electrons support a multipolarity that is strongly $E2$ and suggest $\frac{3}{2}^+$ spin and parity. However, the large A_{22} coefficient for this cascade does not allow the 291-keV level to be $\frac{3}{2}^+$ and is consistent with two ranges of mixing for a $\frac{5}{2}(1)\frac{7}{2}(1,2)\frac{7}{2}$ sequence, one where δ^2 lies between 0.06 and 0.12 and the other between 0.95 and 0.99. The latter is consistent with the conversion coefficient and indicates $\frac{5}{2}^+$ spin and parity for the 291-keV level. The less intense 719-261-keV cascade has an A_{22} coefficient that is consistent with either a $\frac{5}{2}^+$ or a $\frac{7}{2}^+$ assignment. The A_{22} value for the 1117-291 cascade of $-0.20(4)$ has the same sign and is of the same magnitude as the A_{22} value for the 719-291 cascade. This negative sign is contrary to the $\frac{3}{2}^-$ possibility for the 1407-keV level as the F_2 for a $\frac{3}{2}$-$\frac{3}{2}$ dipole sequence has a value of -0.4 as opposed to the $+0.1$ value for a $\frac{5}{2}$-$\frac{3}{2}$ dipole sequence. Consequently $\frac{5}{2}^-$ is fixed as the spin and parity of the 1407-keV level.

The large negative A_{22} value for the 544-435 cascade from the 1010-keV $\frac{5}{2}^-$ level through the 465-keV to the $\frac{3}{2}^+$ level at 30 keV is possible only for $\frac{5}{2}^+$ spin and parity for the 465-keV level.

The 467-431-keV cascade from the 1010-keV $\frac{5}{2}^-$ level through the 642-keV level to the 211-keV $\frac{5}{2}^+$ level has an A_{22} value of $-0.13(2)$. This value eliminates the $\frac{3}{2}^+$ spin possiblity for the 642-keV level. The lowest level that could be a $\frac{1}{2}^+$ level is at 956 keV because it is the only level below 1 MeV that does not populate the $\frac{7}{2}^+$ ground state.

III. DISCUSSION

Several features of the observed structure indicate that the deformation in the region below $Z=64$ is of a somewhat different character than the deformation in the middle of the rare-earth region above $Z=64$. When the $N_\pi N_\nu$ systematics were found by Casten[40] to be a useful tool for estimating deformation, a separate curve was required for the region below $Z=64$ relative to the curve for nuclides above $Z=64$. More recently, Casten, Brenner, and Haustein[41] have identified the P factor denoting an average number of neutron-proton interactions, where $P=N_\pi N_\nu/N_\pi+N_\nu$. They observed that deformation appears to develop beyond P values of about 4. In the region below $Z=64$, the first nuclide beyond the double closed shell at ^{132}Sn with $P=4$ would be ^{148}Ce where $P=8\cdot8/(8+8)=4$. While this approach may not be appropriate for odd-mass nuclides, it does indicate that deformation brought about by increased proton-neutron interactions, particularly those of spin-orbit partner orbitals as suggested by Federman and Pittel,[42] should not be present for even-even Ba and Xe nuclides nor for Ce nuclides with $A<148$. With the level structure of ^{143}La now more fully characterized, it is possible to examine the changes in structure of the La nuclides with $Z=57$ as a function of neutron number near $N=82$ as shown in Fig. 6. It is clear in this figure that it is the presence of the low-lying $\frac{3}{2}^+$ level and the low-lying $\frac{5}{2}^+$ levels beginning at 924 keV that distinguish ^{143}La from ^{141}La and from the neutron-deficient La nuclides.

While the sharp drop in position of the lowest $\frac{3}{2}^+$ level is in contrast to the structure observed for the neutron deficient La nuclides, it is consistent with the structures of the other odd-Z $N=86$ isotones shown in Fig. 7. The systematic behavior of both the low-lying positive parity levels and the negative parity levels can be examined in some detail in this figure. The depressed $\frac{3}{2}^+$ level is observed to be an important feature of these nuclides near the middle of the $Z=50$ to $Z=64$ shell, and to reach its minimum at the half-way point, $Z=57$. It appears that it is likely that this same $\frac{3}{2}^+$ level is the ground state of ^{143,145}Cs. Recent studies of the structure of ^{147}Pr, which is isotonic with ^{143}Cs and ^{145}La, have also indicated the possibility of a $\frac{3}{2}^+$ ground state for ^{147}Pr, and can be used to predict a similar ground state[43] for ^{145}La. It may be observed that in spite of the rapidly changing position of this $\frac{3}{2}^+$ level, the structure of the adjacent even-even $N=86$ core nuclides is undergoing little change.

The second distinguishing feature of these nuclides is the presence of low-lying low-spin negative-parity levels that are strongly populated in beta decay. These levels could be described as arising from the coupling of the single-particle levels with the negative parity 3^- and 1^- levels in the ^{142}Ba core. The downward displacement of 400 keV from the positions of the 3^- and 1^- levels indicates a very strong particle-octupole interaction. Moreover, the strong beta-decay population of these levels is not observed in the decay of isotopic ^{141}Ba to levels of ^{141}La. In ^{140}Ba, the 3^- level is found at 1803 keV. While numerous levels in the energy range from 1500 to 2000 keV were populated in ^{141}La, none of the logft values

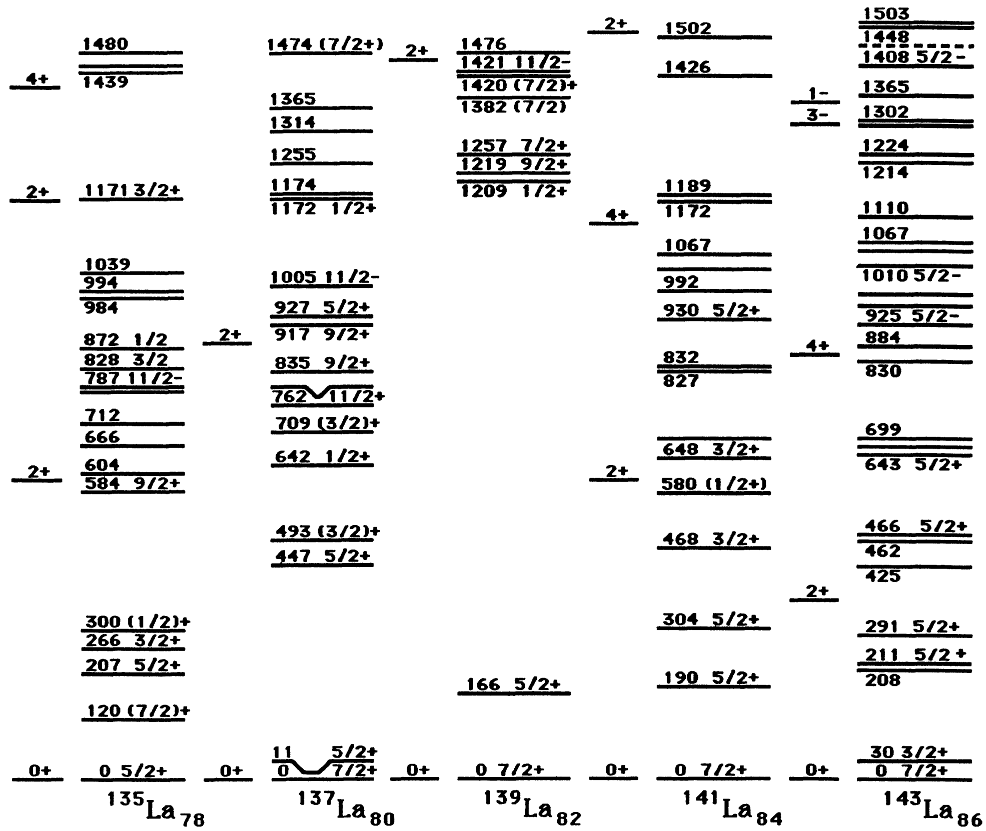

FIG. 6. Systematics of the low-energy levels of the odd-Z La nuclides above and below the closed neutron shell at $N=82$.

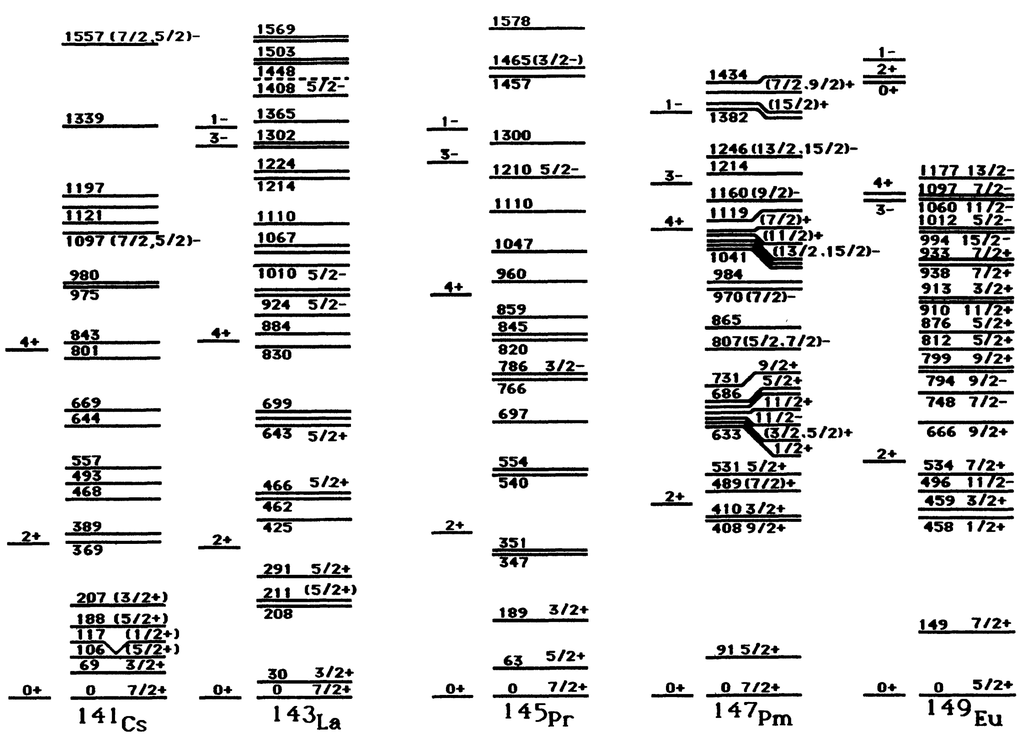

FIG. 7. Systematics of the odd-Z $N=86$ isotones for $54<Z<64$.

were found to be below 6.2.[12]

The most complete isotonic structure is available for ^{149}Eu with just a single hole in the $Z=64$ subshell closure. The data shown are from recent studies by Bondarenko *et al.*[44] and from the Nuclear Data Sheets.[45] The lowest negative-parity level is the $h_{11/2}$ single particle level that becomes the ground state in the Tb nuclides with $Z=65$ when the *gd* subshell is closed at $Z=64$. The excited negative-parity levels arise from coupling the $h_{11/2}$ level with the core 2^+ level, giving rise to levels with spin and parity $\frac{7}{2}^-$, $\frac{9}{2}^-$, $\frac{11}{2}^-$, $\frac{13}{2}^-$, and $\frac{15}{2}^-$ that are shown in Fig. 7. The $\frac{7}{2}$ and $\frac{9}{2}$ levels are depressed relative to the phonon energy, the $\frac{15}{2}$ lies near the phonon energy and the other two are pushed up relative to the phonon. This sequence has been described by Scholten and Blasi[46] in the interacting boson fermion model (IBFM) with some success and the systematics of these levels in the Eu nuclides shown in their paper. The additional $\frac{5}{2}^-$ and $\frac{7}{2}^-$ levels at 1012 and 1097 keV, respectively, appear to arise from the rather weak coupling of the ground state to the 3^- level in the Sm core.

In the $N=82$ nuclides, the $h_{11/2}$ single-particle level rises as neutrons are removed from the $Z=64$ subshell closure from 716 keV in ^{145}Eu to 1421 keV in ^{139}La, at a rate of $\sim$200 keV per pair of protons. The start of a similar rise is observed in the $N=86$ isotones as the $h_{11/2}$ level is found at 650 keV in ^{147}Pm. The negative-parity levels in the odd-mass Pm nuclides have also been described using the IBFM by Scholten and Ozzello[47] but the description is not as good as in the Eu nuclides. Moreover, the experimental data for ^{147}Pm are not as extensive as those for ^{149}Eu. The observation of negative-parity levels as low as 786 keV in ^{145}Pr, 924 keV in ^{143}Pr, 924 keV in ^{143}La, and 1097 keV in ^{141}Cs, with spin below $\frac{7}{2}$, is particularly troublesome. There are cluster-vibration model calculations for the $N=85$ isotones predict the lowering of the *j*-1, *j*-2, and *j*-1 levels as a function of a coupling strength, but not the *j*-3 levels.[48] These low-spin negative-parity levels do rise with the slope of the $h_{11/2}$ level, but at positions that are well below the projected position of the single-particle $\frac{11}{2}$ level. In a classical Nilsson scheme, the degree of deformation required to put the 57th particle in a $\frac{5}{2}^-$ [514] level is above $\varepsilon=0.4$, while the $\frac{3}{2}^-$ [523] level is not encountered until $\varepsilon=0.3$.

The low-lying $\frac{3}{2}^+$ level is equally difficult to account for in the Nilsson model for the 57th proton. Two $\frac{3}{2}^+$ Nilsson orbitals are present in this region, one originating with the $d_{5/2}$ single particle orbital is the [411] orbital that moves up in energy with increased deformation. The other originates with the $g_{7/2}$ single-particle orbital and moves down in energy with increased deformation. It is typically occupied by the 53rd or 55th particle. For this orbital to be the ground state in the Cs nuclides requires either hexadecapole deformation as used by Ekstrom *et al.*[8] or octupole deformation as done by Leander *et al.*[5] and mentioned in the introduction. While there are these methods for accounting for a $\frac{3}{2}^+$ level in the Cs nuclides, it is difficult to do so in the La nuclides, particularly because large deformation is ruled out by the lack of any indication of band structure with a $\frac{5}{2}^+$ member lying 40–50 keV above the $\frac{3}{2}^+$ levels in either ^{143}La or ^{145}Pr. Another possibility is the presence of highly decoupled $\frac{1}{2}^+$ bands that would be most prominent at weak deformation. For $\varepsilon=\sim 0.1$, the $\frac{1}{2}^+$ [420] orbital could lie just above the ground state and give rise to low-lying $\frac{3}{2}$ and $\frac{7}{2}$ levels, with the latter mixing with the single-particle orbital. As this configuration is always present up through $Z=59$, it is the most likely description in the classical Nilsson model.

The new experimental data for the odd-*Z* $N=84$ isotones[10,12,13] show none of the effects described here for the $N=86$ isotones and the observed structures have been well described by various weak coupling approaches.[48–52] A slight lowering of the $\frac{3}{2}^+$ level is obtained by Kortelahti *et al.*[52] as the coupling strength is varied, but not of the magnitude observed in the $N=86$ isotones. Nor are any such effects observed for the nuclides below the $N=82$ closed shell. In view of the difficulties that these levels present to classical Nilsson model calculations and the new data supporting reflection asymmetric structures in the even-even Ba nuclides, it appears likely that full exploration of the effects of octupole, hexadecapole, and higher orders of deformation are fully justified for the nuclides in this mass region. Such calculations have recently been initiated by Cwiok and Nazarewicz[53] with considerable success. In particular, they found that inclusion of β_3, β_4, β_5, and β_6 to result in better fits to the level structures and to the observed magnetic moments. Equally important will be an extension of the experimental investigations to the odd-*Z* $N=88$ isotones to determine some of the structure of ^{143}Cs, establish the ground-state spin and parity as well as the position of the lowest-lying negative-parity levels in both ^{145}La and ^{147}Pr. Such measurements would complement the well-established structures of the higher mass $N=88$ isotones, ^{149}Pm and ^{151}Eu.

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