Levels of ^{93}Rb, ^{93}Sr, and ^{93}Y fed in the decays of ^{93}Kr, ^{93}Rb, and ^{93}Sr†

E. Achterberg, F. C. Iglesias, A. E. Jech,* J. A. Moragues,* D. Otero, M. L. Pérez,* A. N. Proto, J. J. Rossi, and W. Scheuer

Departamento de Física Nuclear, Comisión Nacional de Energía Atómica, Buenos Aires (29), Argentina

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The γ rays and conversion electrons following the β^- decay of ^{93}Kr, ^{93}Rb, and ^{93}Sr have been measured by applying on-line mass-separation techniques to ^{235}U fission products. Level schemes for the three daughter nuclei are proposed based on the study of γ-singles, $\gamma\gamma$-coincidence, and internal-conversion electron spectra. Internal-conversion coefficients were determined for 10 transitions and the deduced multipolarities as well as log*ft* values were combined with known reaction results to assign spins and parities. The half-life for the 758.63-keV isomeric level in ^{93}Y was measured to be 85 ± 15 msec.

[RADIOACTIVITY ^{93}Kr, ^{93}Rb, ^{93}Sr; measured E_γ, I_γ, $\gamma\gamma$ coin, ICC; deduced log*ft*, Λ. ^{93}Y^m; measured $T_{1/2}$. ^{93}Rb, ^{93}Sr, ^{93}Y; deduced levels, J, π. On-line measurement, mass-separated ^{235}U fission products.]

I. INTRODUCTION

In this paper we report the results of our ongoing measurements[1] regarding level schemes of nuclei placed on or near the limit of a region for which stable deformations have been predicted,[2] contained within the closed shells $Z = 28$ and 50, and $N = 50$ and 82. The present investigation is devoted to the levels of ^{93}Rb, ^{93}Sr, and ^{93}Y, fed in the β^- decays of 1.3-sec ^{93}Kr, 5.9-sec ^{93}Rb, and 7.3-min ^{93}Sr, respectively. The activities were produced using on-line mass separation of uranium-fission products, followed by on-line measurements of γ rays and conversion electrons.

Up to now, no level scheme for ^{93}Rb has been proposed, nor has any significant spectroscopic study of the decay of ^{93}Kr been performed. Carlson *et al.*[3] measured the half-life of this decay, and Clifford *et al.*[4] its Q value. Grüter *et al.*,[5] from their measurements on primary fission fragments, reported the existence of a 257-keV, 57-μsec isomeric γ ray in ^{93}Rb. From a ^{93}Kr decay study, Amiel *et al.*[6] reported the four most prominent rays present in the γ spectrum and identified an intense 253-keV line with the 57-μsec isomeric transition. More recently, Grüter,[7] using the same techniques as in Ref. 5, proposed that the isomeric level was depopulated by a 830-259.8-keV cascade. In the present work we propose a scheme of 26 levels containing 76 transitions which correspond to 97% of the total observed γ intensity. We were able to propose tentative parities for eight excited levels and to show that if the isomeric state reported in Ref. 7 is populated in the β decay of ^{93}Kr, it does so only very weakly.

No level scheme for ^{93}Sr has been established up to now nor has any significant study of the ^{93}Rb decay been performed. Its half-life has been determined in Ref. 3 and Macias-Marques *et al.*[8] as well as Clifford *et al.*[4] measured its Q value. Amiel *et al.*[6] reported two γ rays belonging to it and Grüter[7] detected a pair of 1.4-μsec γ rays and, by comparison with the energy of one of the γ rays of Ref. 6, proposed a 1202-keV isomeric state in ^{93}Sr. In this paper we propose a level scheme for ^{93}Sr with 20 levels connected by 37 transitions, which carry 96% of the total observed γ intensity. Spin-parity values are proposed for three levels, and only parity for another three levels. From the results of the present work, if the proposed[7] isomeric state is populated at all in the decay of ^{93}Rb, it does so only very weakly. Furthermore, we show that the $\frac{5}{2}^+$ spin-parity assignment made by Herzog and Grimm[9] for the ^{93}Sr ground state is inconsistent with both their own and our experimental results, which indicate $\frac{5}{2}^-$, $\frac{7}{2}^+$.

The first partial level scheme proposed for ^{93}Y on the basis of Ge(Li)-detector singles γ-ray spectra as well as $\gamma\gamma$ and $\beta\gamma$ coincidences was published by Cavallini, Schussler, and Moussa[10] from an off-line measurement; it contained seven levels connected by eight transitions. Thereafter, using the same techniques, Herzog and Grimm[9] proposed a level scheme comprising 55 transitions within 23 states; spins and parities for the six lowest levels were based on the ^{94}Zr$(d, {}^3$He) reaction work performed by Preedom, Newman, and Hiebert,[11] and for higher-lying levels they were inferred from γ branchings and log*ft* values. In Refs. 3 and 9 the half-life of the ^{93}Sr decay was determined. The most reliable Q-value determinations appear to be those by Macias-Marques *et al.*[8] and Herzog and

Grimm,[9] which agree with the value reported by Bakhru and Mukherjee.[12] Cavallini *et al.*[10] were the first to report the existence of a 759.5-keV isomeric level in ^{93}Y and proposed an $E3$ character for the transition deexciting it by measuring its α_K; however, they did not measure the half-life of the isomeric state. Very similar results are given in Ref. 9. In the present paper we propose a level scheme of 25 levels comprising 69 transitions corresponding to 97% of the total γ-ray intensity observed. We could assign spins and parities for six levels, based on the work of Preedom *et al.* and on our own conversion-electron measurements and $\log ft$ values. Based on $\log ft$ values alone we propose three spin-parity possibilities for most of the other levels, and for some of them, parity as well. We measured the half-life of the 758.63-keV isomeric state to be 85 ± 15 msec and, by determining that it is deexcited by a pure $E3$ transition, added a point to the systematics[13] of these transitions.

II. EXPERIMENTAL PROCEDURES

A. On-line system for production and collection of samples

The Buenos Aires isotope separator on-line facility (IALE Proyect) used in the production of the samples was described in a previous publication.[14] Briefly, a target of uranyl stearate containing ~14 g of ^{235}U was exposed to a thermal neutron flux of about $\sim 5 \times 10^8$ neutrons cm^{-2} sec^{-1}; the rare-gas fission products were conveyed into the ion source of a mass separator and the mass-93 beam was selected.

Two different types of collectors were used to accumulate the activity: an aluminized-Mylar moving tape for singles and coincidence γ-ray measurements, and a special fixed-collector arrangement to determine conversion coefficients. Complete descriptions of the collectors were published in Refs. 14 and 15.

B. γ-ray measurements

1. *Singles γ-ray spectra*

In order to assign properly the transitions to the correct member of the mass-93 chain, the moving-tape collector was operated with different time schedules to vary the Kr-to-Rb-to-Sr-to-Y-activity ratios. Moreover, in order to improve the identification of contaminations, masses 91, 92, and 94 as well as the background were measured separately in special runs.

Comparing the γ spectra recorded in this experiment with those obtained in the internal-conversion measurements taken with a significantly larger source-detector distance, any sum-up peak could be eliminated.

Two 35-cm^3 commercial Ge(Li) detectors were used to record the γ spectra. They had peak-to-Compton ratios of 29 : 1 and 20 : 1, and resolutions of, respectively, 2.2 and 4.0 keV full width at half-maximum (FWHM), at 1.33 MeV. The detector pulses were fed through conventional electronics into a 4096-channel analyzing system provided with a small computer.

The 2.2-keV-resolution detector has a borated sheet very close to the Ge crystal which, through the ^{10}B(n, $\alpha\gamma$) reaction, produces a broad peak at 480 keV (see Figs. 2 and 3). This energy region was carefully studied with the second detector in order to ensure that no significant mass-93 peaks were hidden in it.

The energy calibration of the most important γ rays of the mass-93 activity was made using the energy values given in Ref. 16 for the lines of the ^{56}Co, ^{60}Co, and ^{192}Ir decays and those given in Ref. 17 for the lines of the ^{57}Co decay. Those γ rays, in turn, were used for internal calibration. Mass-93 γ rays having energies above 3.3 MeV were calibrated through their double- and single-escape peaks using a slight extrapolation of the calibration curve; this was supported through well-identified pairs of mass-93 full-energy and double-escape peaks, the latter peaks being below 3.3 MeV.

The relative-efficiency calibrations for both detectors over the range 0.2–3.4 MeV were performed collecting mass 138 on-line and recording the standard ^{138}Xe and ^{138}Cs decay lines.[18] The low-energy region was calibrated using the ^{75}Se standard source[18] with a dummy reproducing the on-line geometry. The resulting efficiency curves were defined within ±10% for the 40–200-keV and 2.0–4.5-MeV ranges, and within ±7% for the 0.2–2.0-MeV range.

Spectra were analyzed with the ANAGAMMA[19] program and the energy calibration was performed with the FALEN[19] program.

2. *$\gamma\gamma$ coincidences*

The $\gamma\gamma$ coincidence measurements were performed with the two Ge(Li) detectors mentioned above. The resolving time of the coincidence circuit was 1 μsec; we kept the activity of the source such that the random events were less than 0.5% of the real coincidences. Coincidence events were stored as 4096×4096 bidimensional data using a magnetic-tape buffer, as described in Ref. 1.

Two separate $\gamma\gamma$ coincidence runs of 10^6 events each were made with a cycling of the moving-tape collector appropriate to obtain saturated activity

TABLE I. γ rays observed in the decay of ^{93}Sr.

Present work Energy (keV)	Present work Relative intensity ^{a}	Herzog and Grimm (Ref. 9) Energy (keV) ^{b}	Herzog and Grimm (Ref. 9) Relative intensity
168.45 ± 0.06	270 ± 30	168.5	254.0 ± 63.6
260.14 ± 0.06	105 ± 6	260.0	102.2 ± 9.5
285.6 ± 0.3	7.1 ± 0.5	285.5	3.9 ± 2.0
346.45 ± 0.03	46 ± 3	346.4	39.6 ± 4.9
377.36 ± 0.08	20.5 ± 1.4	377.4	23.4 ± 3.9
406.80 ± 0.14	5.5 ± 1.1	406.1 ^{c}	16.4 ± 3.6
432.0 ± 0.5	20 ± 7	431.5	29.0 ± 4.8
445.97 ± 0.08	32 ± 4	445.8	28.9 ± 3.0
483.0 ± 0.5	32 ± 7	482.4	28.9 ± 3.2
541.52 ± 0.10	11.4 ± 1.1	541.9	8.7 ± 1.9
546.14 ± 0.20	5.3 ± 1.8	545.6	3.4 ± 1.4
590.18 ± 0.06	1000 ± 60	590.2	1000.0 ± 8.1
611.03 ± 0.12	13 ± 3	610.8	9.3 ± 8.4
663.39 ± 0.25	17.2 ± 1.2	663.4	21.9 ± 3.6
687.89 ± 0.16	7.0 ± 2.0	687.3 ^{c}	5.0 ± 4.4
690.34 ± 0.20	16 ± 4	689.7	13.6 ± 5.0
710.19 ± 0.10	290 ± 30	710.3	315.0 ± 24.6
717.81 ± 0.08	32 ± 9	718.1	25.1 ± 3.5
771.03 ± 0.12	16.9 ± 1.5	771.1	15.7 ± 1.9
788.11 ± 0.22	11.1 ± 1.1	788.7 ^{c}	15.6 ± 1.8
814.64 ± 0.20	8.6 ± 0.8		
834.92 ± 0.10	25.4 ± 1.7	834.8	22.9 ± 2.4
843.93 ± 0.20	7.7 ± 0.7		
858.60 ± 0.16	9.0 ± 0.8	858.9	12.3 ± 1.7
875.86 ± 0.06	345 ± 30	875.8	358.1 ± 29.2
888.26 ± 0.06	335 ± 30	888.2	330.6 ± 27.2
900.72 ± 0.16	12.2 ± 1.0	901.1 ^{c}	8.5 ± 1.1
935.11 ± 0.25	7.4 ± 0.7		
1006.2 ± 0.6 ^{c}	2.4 ± 0.5		
1040.55 ± 0.08	41 ± 3	1040.5	48.6 ± 4.2
1054.72 ± 0.20 ^{c}	4.8 ± 1.5	1054.1 ^{c}	7.1 ± 1.3
1094.14 ± 0.20	29 ± 3	1093.9	27.5 ± 2.9
1122.20 ± 0.18	52 ± 5	{1122.4	34.4 ± 3.0
		{1122.4	23.2 ± 2.1
1196.09 ± 0.10	14 ± 3	1196.4 ^{c}	12.6 ± 1.9
1214.4 ± 0.4	23 ± 10 }	1215.4	38.7 ± 3.5
1216.7 ± 0.4	12 ± 6 }		
1243.30 ± 0.20	11.0 ± 1.0	1243.1	11.8 ± 1.6
1269.28 ± 0.10	109 ± 7	1269.3	110.7 ± 9.9
1277.88 ± 0.24	10.5 ± 1.0	1277.7 ^{c}	10.9 ± 2.6
1308.4 ± 0.6	6.1 ± 1.1	1308.4 ^{c}	7.5 ± 1.0
1320.85 ± 0.10	39 ± 3	1321.2	39.1 ± 6.0
1334.2 ± 0.3	16 ± 4	1334.1	16.6 ± 2.0
1387.9 ± 0.5	45 ± 5	1387.1	41.2 ± 8.2
1434.45 ± 0.14	17 ± 4	1433.9	14.2 ± 1.5
1438.6 ± 0.4	11 ± 3	1439.0	7.6 ± 1.0
1470.0 ± 0.3	11.4 ± 1.1	1469.6	10.9 ± 1.4
1492.4 ± 0.6	5.6 ± 0.9	1491.9 ^{c}	6.2 ± 1.1
1551.2 ± 0.3	13.8 ± 1.5	1551.4	16.2 ± 1.8
1634.13 ± 0.14	20.8 ± 1.6	1634.0	21.7 ± 2.0
1647.66 ± 0.22 ^{c}	11.3 ± 1.2	1647.5	13.3 ± 1.4
1684.79 ± 0.16	8 ± 3	1684.5	11.1 ± 1.3
1694.25 ± 0.10	33.5 ± 2.3	1693.9	41.2 ± 3.5
1698.89 ± 0.10	58 ± 4	1699.0	55.2 ± 4.5
1706.80 ± 0.20	10.5 ± 1.5	1706.5	18.8 ± 1.9
1765.48 ± 0.20 ^{c}	11.6 ± 1.1	1765.4	15.4 ± 1.6
1774.7 ± 0.8 ^{c}	2.5 ± 0.8	1775.0	3.8 ± 0.6
1803.7 ± 0.6	3.6 ± 0.8		
1811.5 ± 0.5	22 ± 4	1811.5	24.1 ± 2.3
		1816.5	4.1 ± 0.8
1928.73 ± 0.14	15 ± 4	1928.7	19.9 ± 1.9
1944.2 ± 0.3	11.1 ± 1.1	1944.8	9.5 ± 1.1
1979.4 ± 0.5	5 ± 3	1979.3	2.4 ± 0.4
2011.7 ± 0.4	5.4 ± 1.0		
		2054.7 ^{c}	3.1 ± 0.6
2064.5 ± 0.5 ^{c}	5 ± 4	2063.9 ^{c}	9.9 ± 1.1
2105.6 ± 0.9	4 ± 3	2105.5 ^{c}	3.7 ± 0.6
2128.3 ± 0.6	4 ± 3		
2177.4 ± 1.5	1.8 ± 0.8	2178.6	3.8 ± 0.5
2196.1 ± 0.5	7.1 ± 1.2		
2230.42 ± 0.16	29 ± 3	2230.6	24.9 ± 2.3
2296.5 ± 0.5	10.1 ± 1.4	2296.5 ^{c}	11.9 ± 1.4
2359.5 ± 0.5 ^{c}	7.5 ± 1.5		
2365.80 ± 0.20 ^{c}	21.3 ± 2.0	2364.5	24.5 ± 3.4
2544.60 ± 0.10 ^{c}	42 ± 6	2543.7	54.3 ± 4.4
		2574.3	1.7 ± 0.5
2688.98 ± 0.20 ^{c}	31 ± 3	2688.3	36.6 ± 2.9
2828.1 ± 0.8 ^{c}	4.3 ± 1.8	2828.5 ^{c}	2.2 ± 0.5
2984.5 ± 1.5	2.0 ± 1.0	2985.4 ^{c}	4.0 ± 0.8
		3006.7	1.9 ± 0.4
		3116.3 ^{c}	1.0 ± 0.3
3414.2 ± 1.5	13 ± 4		
3972.9 ± 2.0 ^{c}	13 ± 6		

[a] The error stated for the intensity normalized to 1000 has not been included in the errors of the other intensities.

[b] The errors are ≤0.2 keV.

[c] Not placed in the level scheme.

for Kr, Rb, and Sr and to keep the Y activity at a negligible level.

C. Internal-conversion-coefficient determination

The method used for internal-conversion-coefficient determination is fully described in Ref. 15. In the present work, for the conversion electrons, we used a 3-cm^2 area, 3-mm depletion depth Si(Li) detector, having a resolution of 6 keV FWHM for the 976-keV line of ^{207}Bi; the γ rays were measured with the above mentioned 2.2-keV resolution detector. Three separate measurements of 4 hours each were carried out in the energy region of 0 to 1 MeV; the collector was changed after each run in order to avoid the growth of ^{93}Y activity. In order to determine the $K/L+\cdots$ ratio for the 168.45-keV transition in ^{93}Y a special run was performed in which the ^{93}Sr activity was enhanced more than 1000 times with respect to the ^{93}Rb one.

The relative γ-efficiency calibration was obtained using the previously determined intensities of γ rays belonging to mass 93. The normalization function was determined by measuring on line the well-known[20] conversion coefficients for the 304-keV transition in ^{85}Kr and the 151-keV transition in ^{85}Rb.

D. Half-life of ^{93}Y^m

We measured the half-life corresponding to the metastable state in ^{93}Y by performing delayed coincidences with the oscilloscope method.[21] Since in the γ spectrum the peak of the 168.45-keV transition depopulating the isomeric level is mounted on a very high background, we used as stop pulses the ones produced by the internal-conversion electrons of the transition in order to reduce the random coincidences; in this way, the ratio between random and real events was kept at about 0.1. The start pulses were generated by the 888.26-keV γ ray. The collector-detector setup was the same as the one used for the conversion-coefficient determinations; the sweeping speed of the oscilloscope was 20 msec/cm.

TABLE II. $\gamma\gamma$-coincidence results for ^{93}Sr decay.

Gate transition [a] (keV)	Coincident transitions [b] (keV)
168	590.18
260	875.86, 1122.20, 1434.45, 1438.6, 1551.2?, 1634.13
346	590.18, 710.19
432	875.86
446	346.45?, 483.0, 590.18, 710.19?, 888.26
483	445.97, 875.86, 888.26?, ~1215?, 1334.2
590	168.45, 346.45, 710.19, 858.60, 1040.55?, 1269.28, 1320.85, 1387.9, 1765.48?, 2230.42
663	590.18?
690	888.26?
710	346.45, 590.18, 1269.28, 1387.9
876	260.14, 690.34, 1122.20, ~1215?, 1694.25, 1698.89
888	445.97, 1040.55
1041	590.18?, 888.26?
1094	834.92?
1122	260.14?, 875.86?
~1215	483.0
1269	590.18, 710.19
1321	590.18
1388	590.18, 710.19
1434	260.14
1634	260.14?
1694	875.86
1699	875.86
2230	590.18?

[a] With gates placed at 377, 835, 1707, 1812, 2366, 2545, and 2689 keV, no coincidences were observed.
[b] "?" means doubtful coincidence.

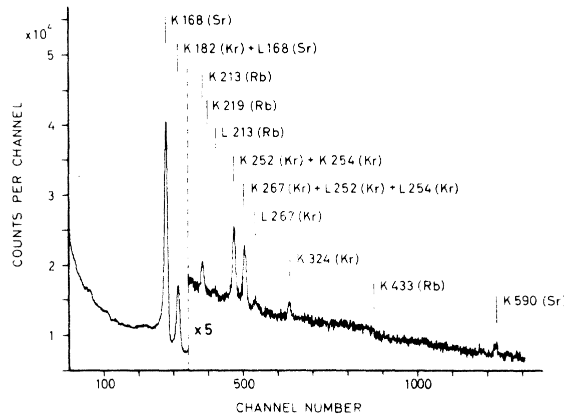

FIG. 1. Partial on-line conversion-electron spectrum of the decays of ^{93}Kr, ^{93}Rb, and ^{93}Sr, recorded with a Si(Li) detector. The spectrum is the sum of three spectra recorded during 4 hours each.

III. EXPERIMENTAL RESULTS

A. ^{93}Sr decay

1. Singles and coincidence γ-ray spectra

The positive identification of the γ rays belonging to the ^{93}Sr decay was made by comparing a

TABLE III. Results of the conversion-coefficient determinations.

Parent nucleus	E_γ (keV)	$\alpha_K \times 10^3$ $\langle K/L+\cdots\rangle$	Proposed multipolarity [a]
^{93}Kr	181.99	50 ± 6	$M1+(35\pm10)\%$ $E2$
^{93}Kr	252.33	$10.8\le\alpha_K\le14.2$ [b]	$M1$ ($\le18\%$ $E2$) [b]
^{93}Kr	253.58	$10.8\le\alpha_K\le13.7$ [b]	$M1$ ($\le16\%$ $E2$) [b]
^{93}Kr	266.78	23.3 ± 2.3	$E2$ ($\le23\%$ $M1$)
^{93}Kr	323.92	5.1 ± 0.9	$M1$
^{93}Rb	213.39	38 ± 8	$E2+(50\pm20)\%$ $M1$
^{93}Rb	219.22	≤10	$E1$
^{93}Rb	432.62	≤ 1.5	$E1$
^{93}Sr	168.45	670 ± 70 ⟨3.62 ± 0.23⟩	$E3$
^{93}Sr	590.18	1.6 ± 0.4	$M1$ ($\le71\%$ $E2$)

[a] By comparison with the theoretical conversion coefficients given in Ref. 22. The upper limits for the percentage of admixtures have been obtained using not the experimental values for the conversion coefficients themselves, but the appropriate end of the corresponding error bar.
[b] See Sec. III C 2.

spectrum in which the ^{93}Sr activity was enhanced about 60 times with respect to the ^{93}Rb one, with the saturation spectrum, as well as other spectra recorded with quite different enhancement conditions. The averaged results of several runs of energy and intensity determinations are given in Table I. They are in good agreement with the ones of Herzog and Grimm.[9] We were able to assign 77 γ rays to the ^{93}Sr decay, 12 of which were not reported previously. We did not see five γ rays proposed in Ref. 9 as belonging to this decay, two of which (1816.5 and 2574.3 keV) might be due to sum-up effects. Table II contains the results of our $\gamma\gamma$ coincidence measurements.

2. *Conversion-coefficient measurements and $^{93}Y^m$ half-life*

Figure 1 shows a partial on-line electron spectrum of the decays of ^{93}Kr, ^{93}Rb, and ^{93}Sr. It contains information on two transitions in ^{93}Y. Regarding the strong 168.45-keV transition, it is seen that its $L+\cdots$ peak overlaps the K peak of the 181.99-keV transition in ^{93}Kr decay. We determined its $K/L+\cdots$ ratio in a special run, as described in Sec. II C.

All the K-conversion coefficients obtained in this work are collected in Table III. Previous measurements[9, 10] existed only for the one corresponding to the 168.45-keV transition in ^{93}Y. We assigned the proposed multipolarities by comparing our experimental values with the theoretical ones given in Ref. 22.

The half-life of the 758.63-keV isomeric state was measured to be 85 ± 15 msec, using the method described in Sec. II D.

B. ^{93}Rb decay

1. *Singles and coincidence γ-ray spectra*

Figure 2 shows a typical partial γ-ray spectrum taken with the ^{93}Rb activity enhanced with respect to the ^{93}Kr one by a factor of 13. The energies and relative intensities of the 45 γ rays assigned to the ^{93}Rb decay are listed in Table IV.

Our $\gamma\gamma$-coincidence results are summarized in

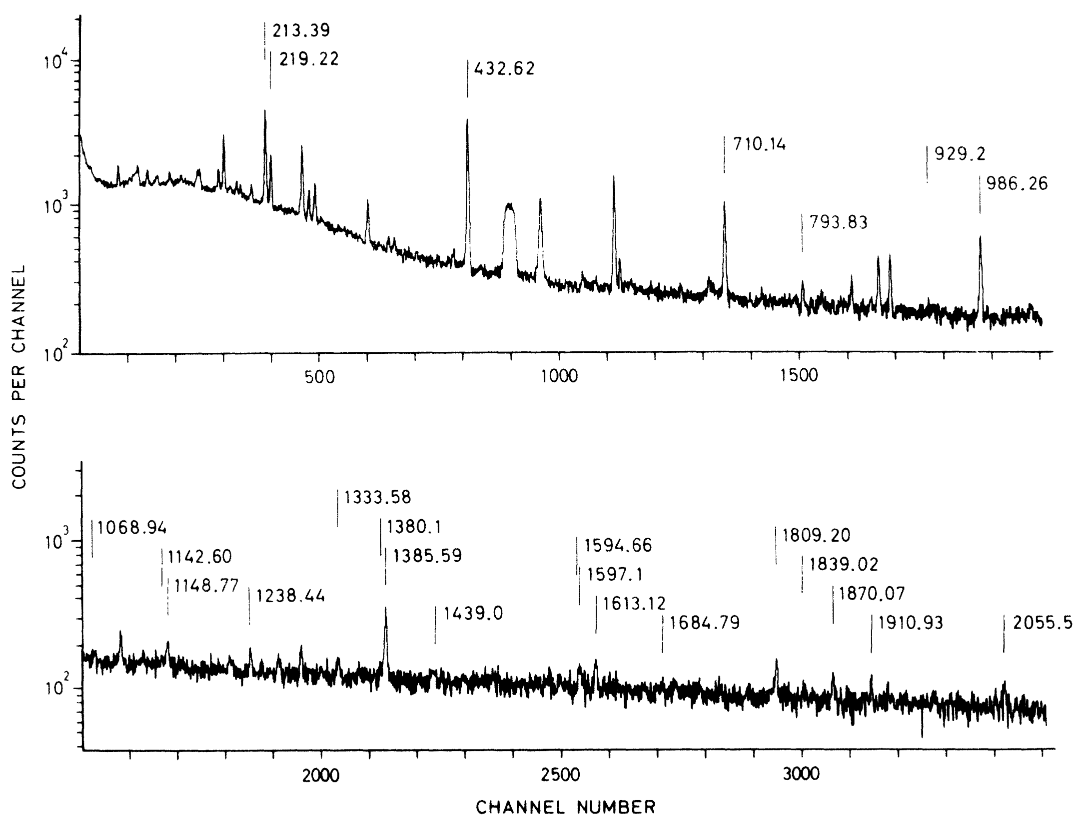

FIG. 2. Partial γ spectrum with enhanced Rb activity. The spectrum is the result of the sum of 1200 spectra, each recorded during 20 sec after switching off the separator beam and a waiting period of 2.5 sec. The activity-accumulation period was of 30 sec in each cycle. Only the Rb decay full-energy peaks are labeled with the corresponding energy value. Concerning the broad peak at channel number ~900, see Sec. II B 1.

TABLE IV. γ rays observed in the decay of ^{93}Rb.

Energy (keV)	Relative intensity [a]	Energy (keV)	Relative intensity [a]
213.39±0.05	385 ±30	2055.5 ±0.4	63 ± 5
219.22±0.06	137 ± 9	2230.42±0.12 [b]	21 ± 5
432.62±0.05	1000 ±50	2293.58±0.24	13.4± 2.1
710.14±0.04	250 ±40	2456.1 ±0.3 [b]	18 ± 3
793.83±0.06	49 ±10	2491.3 ±0.3	18 ± 7
929.2 ±0.5	13 ± 3	2506.41±0.20	24 ± 6
986.26±0.04	342 ±30	2706.03±0.13	42 ± 4
1068.94±0.12 [b]	20.9± 1.9	2946.85±0.20	35 ± 4
1142.60±0.12	26 ± 3	2999.0 ±0.4	38 ± 5
1148.77±0.06	79 ± 5	3212.2 ±1.1	17 ± 6
1238.44±0.08	71 ± 7	3371.9 ±0.3	40 ± 7
1333.58±0.06	36 ± 5	3459.6 ±0.3	145 ±19
1380.1 ±0.5	27 ± 3	3478.4 ±0.5	13 ± 6
1385.59±0.21	80 ±50	3503.7 ±0.5	28 ± 8
1439.0 ±0.7 [b]	22 ± 6	3804.84±0.17	45 ± 5
1594.66±0.21	25 ± 3	3868.27±0.13	47 ±13
1597.1 ±0.8	27 ± 3	3885.7 ±0.6 [b]	21 ± 4
1613.12±0.06	93 ±13	3935.8 ±0.4	39 ± 7
1684.79±0.08 [b]	15 ± 5	4272.8 ±0.8 [b]	16 ± 7
1809.20±0.07	124 ±11	4879.0 ±1.5 [b]	15 ± 5
1839.02±0.22	17 ± 5	5135.7 ±1.5	31 ±25
1870.07±0.06	85 ± 7	5269.9 ±1.7	32 ±24
1910.93±0.10	40 ±11		

[a] The error stated for the intensity normalized to 1000 has not been included in the errors of the other intensities.
[b] Not placed in the level scheme.

TABLE V. $\gamma\gamma$-coincidence results for ^{93}Rb decay.

Gate transition [a] (keV)	Coincident transitions [b] (keV)
213	219.22, 710.14, 929.2
219	213.39, 710.14
433 [c]	710.14, 2456.1?
710 [c]	432.62
794	986.26
986	793.83?

[a] With gates placed at 1149, 1238, 1613, 1809, 1870, 1911, 2056, 2438 (double escape peak of 3460), 2506, 2783 (double escape peak of 3805), and 2846 (double escape peak of 3868) keV, no coincidences were observed.
[b] "?" means doubtful coincidence.
[c] The coincidences at 433-710.14 keV and 710-432.62 keV were attributed to this decay since the transitions of similar energies present in the ^{93}Sr decay would give rise to significantly weaker coincidence peaks.

Table V. Since the coincidences were recorded simultaneously for ^{93}Kr, ^{93}Rb, and ^{93}Sr with their activities at saturation, the fact that 60% of ^{93}Rb decays to the ^{93}Sr ground state (Sec. III B 2) limited our results to the dominant cascades in this nucleus.

2. *Conversion-coefficient and ground-state β-feeding determinations*

The results of the internal-conversion measurements for the 213.39-, 219.22-, and 432.62-keV transitions in ^{93}Sr are listed in Table III. For the last two we only determined an upper limit.

Cavallini *et al.*[10] and Bakhru and Mukherjee[12] determined that, within the experimental errors, the β feeding to the ^{93}Y ground state is zero and Talbert *et al.*[23] established that only about 1.7% of the decays of ^{93}Rb give rise to delayed-neutron emission. From these results and our γ-ray intensities and level schemes, we calculated the β feeding to the ^{93}Sr ground state following the procedure described in detail in Sec. III A 4 of Ref. 1, arriving at a value of 59±3 per hundred disintegrations.

C. ^{93}Kr decay

1. *Singles and coincidence γ-ray spectra*

Figure 3 shows a typical partial γ-ray singles spectrum with the ^{93}Kr activity enhanced with respect to the ^{93}Rb one by a factor of 8. In Table VI are given the energies and relative intensities of the 84 γ rays we assigned to the ^{93}Kr decay. Our coincidence measurements showed that the intense 253-keV peak actually corresponded to a doublet, that both components of it were in direct cascade and that one of them deexcites the 505.91-keV level (see Fig. 6). The intensities of the components have been obtained through the quantitative analysis of those measurements and the corresponding energies were determined by a rather involved calculation[24] based on all the above mentioned results. Our $\gamma\gamma$-coincidence results are listed in Table VII.

2. *Conversion-coefficient and ground-state β-feeding determinations*

The five internal-conversion coefficients determined for the ^{93}Kr decay are listed in Table III. The multipolarities for the 252.33- and 253.58-keV transitions were deduced[24] as follows: (a) The ratio of the total electron to the total γ intensities obtained from the composite peaks and the γ-ray intensity ratio for both transitions as determined from the quantitative $\gamma\gamma$-coincidence analysis, and assuming different electron-intensity ratios for the transitions, leads to only two possible multipolarity combinations for them: $E2$ for the 252.33-keV transition and $E1$ for the 253.58-keV transition, or $M1(E2)$ for both of them; (b) since the two transitions link in cascade the ground and 505.91-keV states which, as shown in Sec. IV C 2, have the same parity, both must be either parity changing or parity conserving; consequently $M1(E2)$ is the only possibility for each of them. The calculations performed[24] imply that it is not possible for both transitions to have the highest possible $E2$ admixture.

Figure 1 shows that the K peaks of the 181.99- and 266.78-keV transitions overlap with $L+\cdots$ peaks of other transitions. The contribution of the 168.45-keV transition to the first of those peaks was subtracted using its experimental $K/L+\cdots$ ratio, determined as described in Sec. III A 2. Since a similar procedure could not be applied to obtain the corresponding ratios for the 253-keV doublet, the $L+\cdots$ contribution to the second peak, arising from that doublet, was subtracted using the corresponding theoretical[22] $K/L+\cdots$ values.

For the intensity of the β branch to the ^{93}Rb ground state we obtained a value of 0 ± 5 per hundred disintegrations, using the same procedure as for the ^{93}Sr ground-state feeding.

IV. LEVEL SCHEMES

The level sequences we propose for ^{93}Y, ^{93}Sr, and ^{93}Rb were constructed using the experimental results reported in Sec. III. In Figs. 4 and 6 asterisks identify γ rays which fit twice in the level schemes; all these were placed on the basis of energy sums only and, in some cases, their intensity for each location was limited from intensity-balance considerations for the levels they are linked with.

For the proposals of spins and parities from transition multipolarities and $\log ft$ values, we have followed strictly the criteria established by the Nuclear Data Group[25] and by Raman and Gove.[26] We used two kinds of arguments, as distinguished in Ref. 25: strong arguments leading to unambiguous assignments, and weak arguments leading to tentative assignments. The $\log ft$ values were calculated[27] taking into account for each level the balances of our transition intensities per hundred decays, the half-lives of the decays as given in Ref.

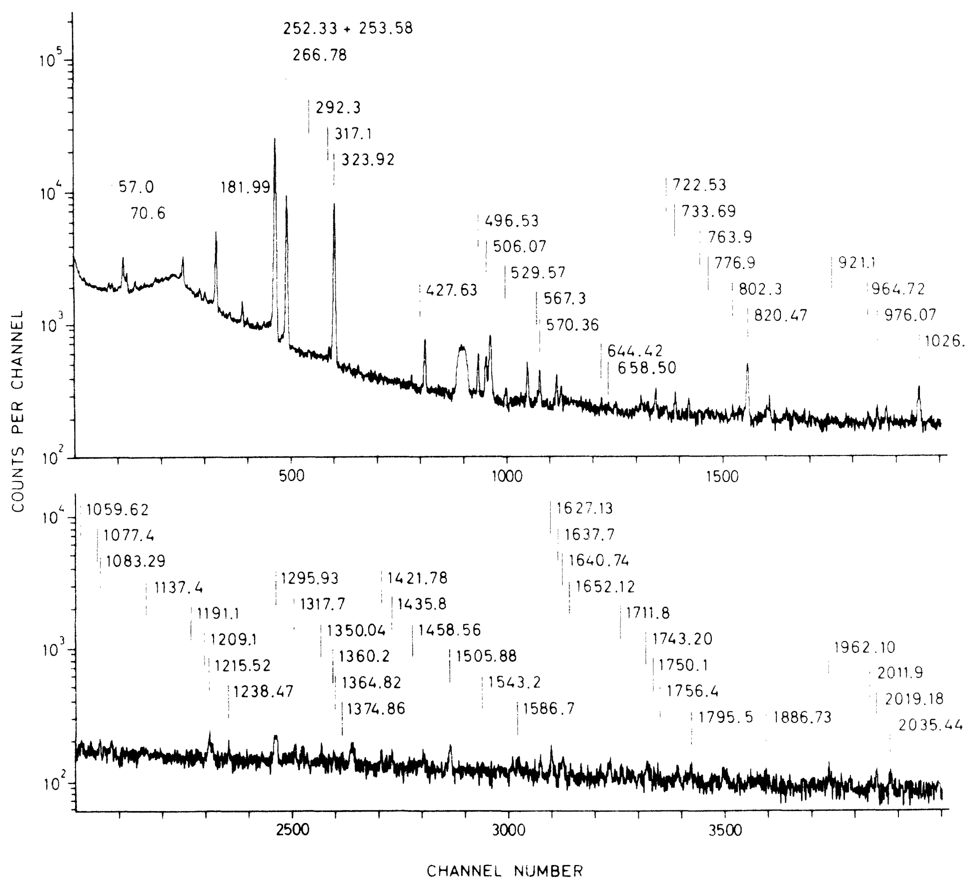

FIG. 3. Partial γ spectrum with enhanced Kr activity. The spectrum is the sum of 4320 spectra, each accumulated during the first 3 sec of the activity growth. Only the Kr decay full-energy peaks are labeled with the corresponding energy value. Concerning the broad peak at channel number ~900, see Sec. II B 1.

TABLE VI. γ rays observed in the decay of ^{93}Kr.

Energy (keV)	Relative intensity [a]	Energy (keV)	Relative intensity [a]
57.0 ± 0.6	28 ± 10	1435.8 ± 0.3	27 ± 4
70.6 ± 0.6	110 ± 40	1458.56 ± 0.18	10.5 ± 2.1
181.99 ± 0.02	223 ± 15	1505.88 ± 0.13	64 ± 7
252.33 ± 0.25	1000 ± 100	1543.2 ± 0.4	12 ± 3
253.58 ± 0.25	1505 ± 150	1586.7 ± 0.3	27 ± 4
266.78 ± 0.02	855 ± 40	1627.13 ± 0.06	56 ± 8
292.3 ± 0.6	6.4 ± 1.5	1637.7 ± 0.5	26 ± 7
317.1 ± 0.3	9.1 ± 2.0	1640.74 ± 0.22	61 ± 7
323.92 ± 0.02	1000 ± 50	1652.12 ± 0.24	13.2 ± 1.9
427.63 ± 0.16	4.0 ± 1.5	1711.8 ± 0.3	14 ± 3
496.53 ± 0.03	61 ± 5	1743.20 ± 0.19	32 ± 5
506.07 ± 0.17	75 ± 10	1750.1 ± 0.7	9.0 ± 2.0
529.57 ± 0.08	17.6 ± 2.3	1756.4 ± 0.4	7.4 ± 1.8
567.3 ± 0.7	7.4 ± 2.0	1795.5 ± 0.3	28 ± 3
570.36 ± 0.12	44 ± 3	1886.73 ± 0.19	16.7 ± 2.4
644.42 ± 0.12 [b]	11.3 ± 1.6	1962.10 ± 0.17 [b]	41 ± 5
658.50 ± 0.10	12 ± 3	2011.9 ± 0.3	9 ± 4
722.53 ± 0.11	10.2 ± 2.0	2019.18 ± 0.10	27 ± 4
733.69 ± 0.06 [b]	30 ± 5	2035.44 ± 0.12	51 ± 7
763.9 ± 0.4	4.6 ± 1.4	2181.44 ± 0.16	29 ± 6
776.9 ± 0.4	9.6 ± 1.2	2350.04 ± 0.08	164 ± 21
802.3 ± 0.4	3.9 ± 1.5	2412.5 ± 0.6 [b]	6.2 ± 1.9
820.47 ± 0.02	135 ± 10	2496.44 ± 0.09	56 ± 10
921.1 ± 0.5 [b]	8.4 ± 1.8	2549.9 ± 0.6	13 ± 4
964.72 ± 0.24 [b]	6.3 ± 2.0	2560.6 ± 0.5 [b]	23 ± 3
976.07 ± 0.15	25.8 ± 2.5	2589.6 ± 0.3	11.0 ± 2.0
1026.09 ± 0.05	62 ± 7	2603.25 ± 0.07	104 ± 10
1059.62 ± 0.20	19.0 ± 1.9	2626.3 ± 0.5	6.7 ± 2.2
1077.4 ± 0.7	3.4 ± 1.0	2810.8 ± 0.3	10.6 ± 2.5
1083.29 ± 0.18	20.8 ± 2.3	2856.8 ± 0.5	45 ± 10
1137.4 ± 0.3 [b]	19 ± 5	2957.4 ± 0.3 [b]	12 ± 4
1191.1 ± 0.4	4.3 ± 1.8	2972.8 ± 0.5	6.8 ± 2.2
1209.1 ± 0.4	5.4 ± 1.3	3151.0 ± 0.9 [b]	8.1 ± 1.8
1215.52 ± 0.13 [b]	58 ± 7	3171.0 ± 0.9	5.7 ± 1.8
1238.47 ± 0.17	21 ± 5	3220.9 ± 1.1 [b]	5.3 ± 2.0
1295.93 ± 0.17	45 ± 4	3227.3 ± 0.4	21 ± 4
1317.7 ± 0.3	30.6 ± 2.5	3298.9 ± 0.8	15 ± 3
1350.04 ± 0.10	19 ± 4	3356.4 ± 0.9 [b]	4 ± 3
1360.2 ± 0.6	6.6 ± 1.9	3407.6 ± 0.8	13 ± 3
1364.82 ± 0.17	17 ± 5	4128.1 ± 1.0	9 ± 7
1374.86 ± 0.25	10.0 ± 1.6	4369.1 ± 0.7	5 ± 3
1421.78 ± 0.15	28 ± 4	4672.2 ± 0.6	8 ± 4

[a] The error stated for the 323.92-keV γ-ray intensity has not been included in the errors of the other intensities.

[b] Not placed in the level scheme.

3, and the Q_β values published in Ref. 9 for the ^{93}Sr decay and in Ref. 4 for the ^{93}Rb and ^{93}Kr decays. In cases where levels are supported by transitions which fit twice in the level scheme, we give the range of possible β-feeding intensities and used its lower limit to calculate the logft value, since this leads to the broadest possible set of J^π assignments.

TABLE VII. $\gamma\gamma$-coincidence results for ^{93}Kr decay.

Gate transition [a] (keV)	Coincident transitions [b] (keV)
182	~253?, 323.92, 2350.04, 2496.44
~253	~253, 570.36, 1627.13, 1637.7, 2350.04, 2496.44, 2603.25, 2957.4?
267	1295.95, 1421.78
324	181.99, 496.53, 1026.09, 2350.04?, 2496.44?
497	323.92
570	~253, 323.92
921	~253?
976	~253?, 323.92?
1026	~253?, 266.78?, 323.92
1422	~253?, 266.78?
1627	~253
1962	~253?
2350	~253, 323.92
2496	~253
2603	~253

[a] With gates placed at 506, 530, 723, 734, 820, 1216, and 2857 keV no coincidences were observed.

[b] "?" means doubtful coincidence.

A. Scheme for ^{93}Y

1. Level energies

The level scheme for this nucleus is shown in Fig. 4. It contains 69 transitions (97% of the total observed γ intensity) within a frame of 25 levels. The levels at 590.18, 758.63, 875.86, 1136.02, 1300.28, 1646.84, 1911.13, 2092.77, 2258.22, 2570.04, 2574.76, 2687.44, 2770.06, and 2820.62 keV are supported by $\gamma\gamma$ coincidences, energy sums, and intensity balances.

The remaining levels are built only on the basis of energy combinations and intensity balances. All of them are connected to other levels by at least three transitions, except the level at 3883.53 keV, defined by only two transitions.

From our 24 excited levels, 14 coincide with levels proposed by Herzog and Grimm.[9] We have not confirmed eight other ones proposed by these authors. We did not see any of the coincidences sustaining their levels at 1853.9, 2543.7, and 2783.3 keV, which, by the intensities of the singles γ rays, we should have seen if they existed. Their levels at 1307.3 and 1852.5 keV are sustained by coincidences but supported by only one and two transitions, respectively. We detected the same coincidences (one clearly and the other doubtfully) but we related them to levels we propose at 1593.63 and at 3413.93 keV, each supported by three transitions. We barely see the coincidence that supports their level at 2355.6 keV but, as we did not

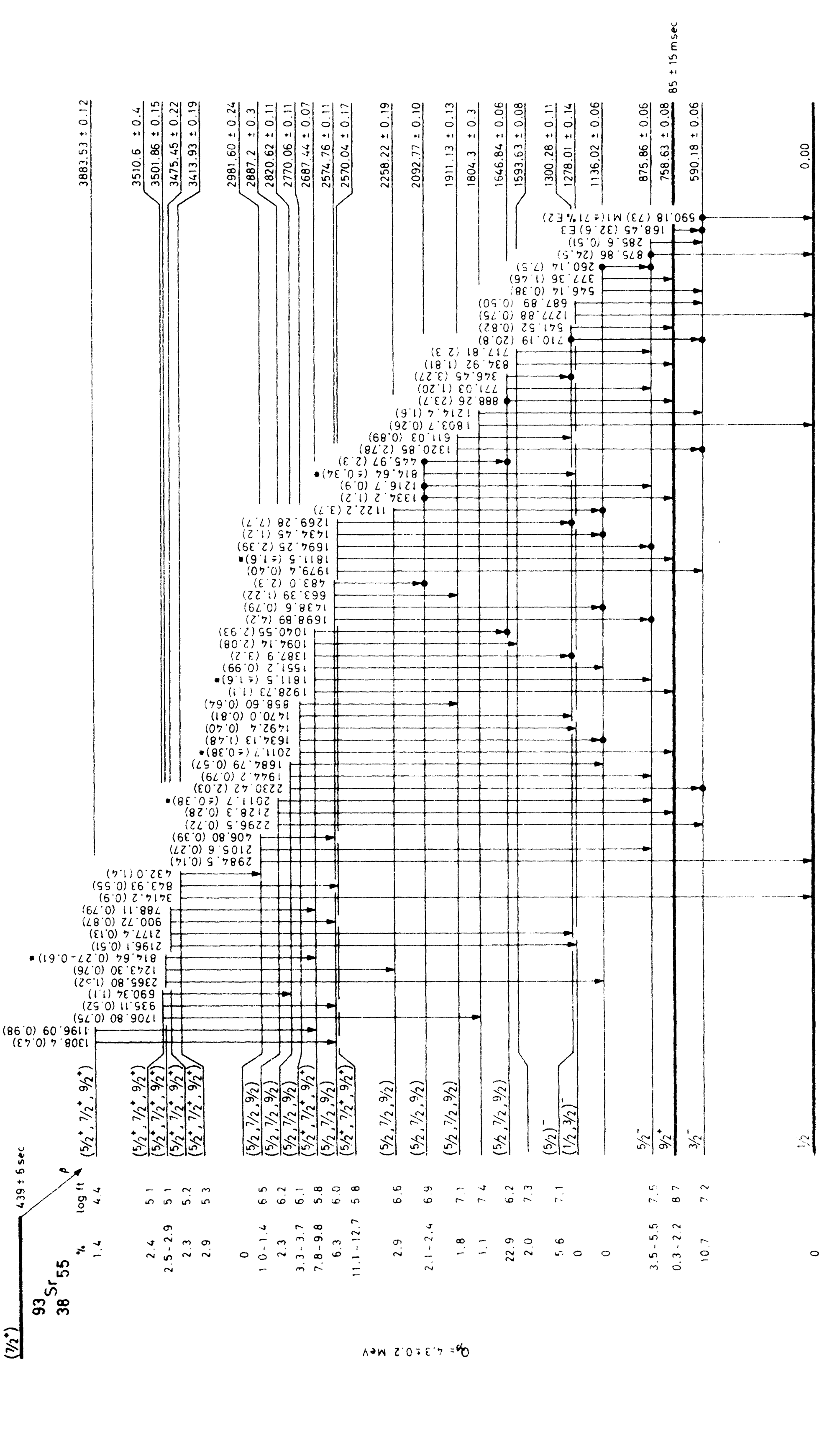

FIG. 4. Level scheme for ^{93}Y. Transition intensities per 100 disintegrations are given within parentheses. Coincidence relations are marked by dots. Doubly placed γ rays are marked with asterisks. Q_β and $T_{1/2}$ of ^{93}Sr were taken from Refs. 9 and 3, respectively. β^- feeding intensity ranges were calculated as described in Sec. IV.

find any other transition that would link this level with other ones, we did not include it in our scheme. For their 2364.5-keV level (sustained by two transitions), while there is a mention of a coincidence in the text of Ref. 9, it is not shown in Fig. 2(b) of that reference, nor indicated in their level scheme. We did not see any coincidences to support this level. Their 3006.7-keV level, proposed on the basis of sum combinations only, is supported by only two transitions, of which we did not see the 3006.7-keV γ ray.

2. *Discussion of spin-parity assignments*

Results based on strong arguments. We identify our four lowest levels in ^{93}Y (see Fig. 4) with the levels at 0, 0.599, 0.755, and 0.890 MeV observed (with an error of ±20 keV) by Preedom *et al.*[11] in the ^{94}Zr$(d,{}^3$He$)^{93}$Y reaction. For these levels, the authors of Ref. 11 determined J^π values of, respectively, $\frac{1}{2}^-, \frac{3}{2}^-$; $\frac{3}{2}^-, \frac{1}{2}^-$; $\frac{9}{2}^+$; and $\frac{5}{2}^-$, by comparing the experimental angular distributions with distorted-wave calculations in the finite-range approximation. For our levels at 1278.01 and 1300.28 keV we propose the identification with the unresolved doublet at 1.28 MeV found by Preedom *et al.*,[11] for whose components they proposed $J^\pi = \frac{5}{2}^-$ and $\frac{3}{2}^-, \frac{1}{2}^-$. This implies that the possible J^π values for both our levels are $\frac{1}{2}^-$, $\frac{3}{2}^-$, and $\frac{5}{2}^-$. For the other two levels observed in Ref. 11 it is very difficult to make an unique identification with any of ours.

From the multipolarity of the 168.45-keV transition that connects the $\frac{9}{2}^-$, 758.63-keV level with the 590.18-keV level (having $J^\pi = \frac{3}{2}^-, \frac{1}{2}^-$ according to Ref. 11) we establish unequivocally $J^\pi = \frac{3}{2}^-$ for the latter one.

Negative parity was confirmed for the ground state from the multipolarity we determined for the 590.18-keV transition in agreement with Preedom *et al.*

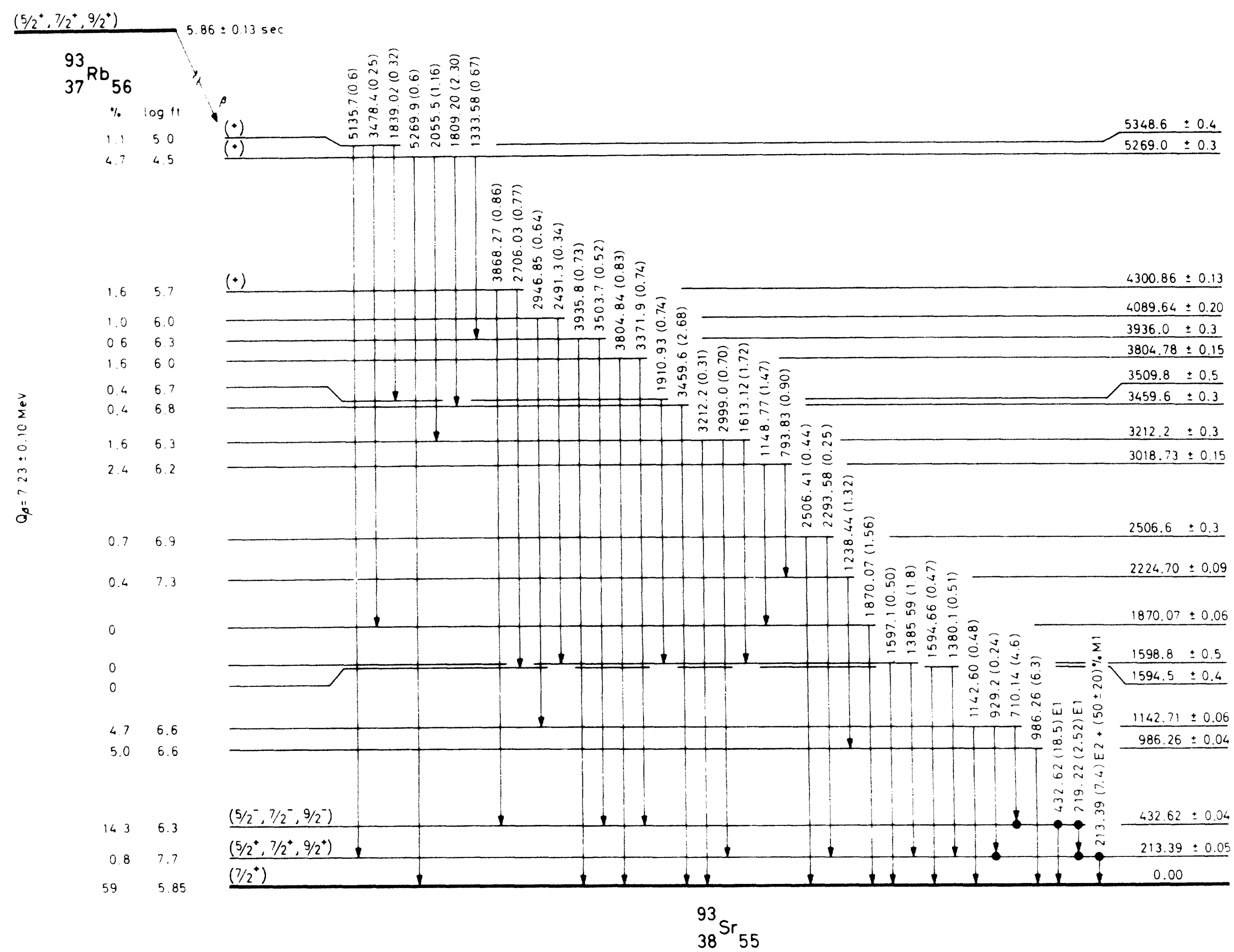

FIG. 5. Level scheme for ^{93}Sr. Transition intensities per 100 disintegrations are given within parentheses. Coincidence relations are marked by dots. Q_β and $T_{1/2}$ of ^{93}Rb were taken from Refs. 4 and 3, respectively.

In Sec. IV B 2, using strong arguments, we limit the J^π values for the ^{93}Sr ground state to $\frac{5}{2}^-$, $\frac{7}{2}^+$. Consequently, the $J^\pi = \frac{1}{2}^-$ possibility[11] for the 1300.28-keV level is excluded by the logft value we obtained for it.

Our logft values for the β decays to the levels at 2570.04, 2687.44, 3413.93, 3475.45, 3501.86, 3510.6, and 3883.53 keV in ^{93}Y, determine an allowed character for each of these β feedings. Therefore, these levels have the same parity as the ^{93}Sr ground state.

Results based on weak arguments. Our spin-parity assignments for the levels with energy nigher than 1.6 MeV (see Fig. 4) are based on the proposed $J^\pi = (\frac{7}{2}^+)$ for the ^{93}Sr ground state (see Sec. IV B 2) together with the character of their β feedings. With the same reasoning, we obtain $J^\pi = (\frac{5}{2})^-$ for the 1300.28-keV level and, therefore, by exclusion, the only possibilities for the 1278.01-keV level are $(\frac{1}{2}, \frac{3}{2})^-$.

Comparison with the results of Ref. 9. We shall now compare our J^π assignments with those proposed by Herzog and Grimm. Proceeding in a similar way as we just did, they arrived at the same J^π values we propose for the ground state and the first three excited levels. For the spin of the levels at 1136.02 and 1646.84 keV these authors proposed $(\frac{7}{2})$, based only on weak arguments. For the 1300.28-keV level our $(\frac{5}{2})^-$ assignment is coincident with the proposal of Ref. 9. The $(\frac{3}{2})^-$, 1307.3-keV level proposed by Herzog and Grimm as the other component of the 1.28-MeV doublet of Ref. 11 is not confirmed in the present work, but instead we propose the $(\frac{1}{2}, \frac{3}{2})^-$, 1278.01-keV level.

In Ref. 9, the $J^\pi = \frac{5}{2}^+$ proposed for the levels at 2574.76 and 2687.44 keV is based on the ^{93}Sr ground-state spin-parity they use and on the γ branching to the ground state and to the 758.63-keV level. As we discuss in Sec. IV B 2, the $J^\pi = \frac{5}{2}^+$ assignment for the ^{93}Sr ground state is wrong and, furthermore, we did not see the ground-state transitions from these two levels.

The parities of the other levels are based on their assignment for the J^π of the ^{93}Sr ground state and on J^π-assignment rules from logft values which are inconsistent with those given by the Nuclear Data Group.[25]

B. Scheme of ^{93}Sr

1. Level energies

The level scheme we propose is shown in Fig. 5. It includes 37 transitions (96% of the observed total γ intensity) within a frame of 20 levels. The levels at 213.39, 432.62, 986.26, and 1142.71 keV are supported by $\gamma\gamma$ coincidences, as well as by energy sums and intensity balances. The set of levels at 1870.07, 2224.70, and 3018.73 keV is based on energy combinations and intensity balances; moreover, there exist coincidences (see Table V) supporting the placements of the two higher levels.

The remainder of the levels are built using only energy sums and intensity balances. The levels at 1598.8, 3212.2, and 5269.0 keV are connected to other levels by at least four transitions, the levels at 1594.5, 3936.0, and 5348.6 keV, by three transitions, and the six remaining levels, by only two transitions.

Searching for the 770.0-keV γ ray deexciting the 1.4 ± 0.4-μsec isomeric level in ^{93}Sr proposed by Grüter[7] from his studies on primary fission fragments, we determined that in the decay of ^{93}Rb its feeding has an intensity of <0.01 disintegrations per 100 decays.

2. Discussion of spin-parity assignments

Results based on strong arguments. The logft values corresponding to the β feeding to the $\frac{3}{2}^-$, 590.18-keV and $\frac{9}{2}^+$, 758.63-keV excited levels in ^{93}Y are consistent with allowed and first forbidden unique and nonunique decays. According to this, we restricted the possible J^π values for the ground state of ^{93}Sr to $\frac{5}{2}^-$ and $\frac{7}{2}^+$. This result is in disagreement with the scarce systematics of ground-state J^π for $Z = 38$ and N even (^{89,91}Sr) and with the single-particle model prediction, which suggest $\frac{5}{2}^+$.

From the multipolarities determined in the present work for the 213.39, 219.22, and 432.62-keV transitions (see Table III), we established unambiguously that the parity of the level at 213.39 keV is the same as that of the ground state, and that the level at 432.62 keV has the opposite one.

Due to the allowed character we found for their β feedings, the levels at 4300.86, 5269.0, and 5348.6 keV in ^{93}Sr must have the same parity as the ^{93}Rb ground state.

Results based on weak arguments. For the ^{93}Sr ground state we preferred a $(\frac{7}{2}^+)$ spin-parity assignment since, from the Nilsson diagram, one would require a totally unrealistic deformation ($\delta > 0.6$) to bring the [532] $\frac{5}{2}^-$ neutron level down to the appropriate energy. We also discarded the [550] $\frac{1}{2}^-$ Nilsson level because the decoupling factor for it is about -5.5, and thus the head of the band must be $\frac{3}{2}^-$ or $\frac{7}{2}^-$. In view of these results, the most probable values for the spin-parity of the levels at 213.39 and 432.62 keV are ($\frac{5}{2}^+$ to $\frac{9}{2}^+$) and ($\frac{5}{2}^-$ to $\frac{9}{2}^-$), respectively.

The J^π we propose for the ^{93}Rb ground state in Sec. IV C 2 and the allowed character of the β feedings indicate a (+) parity for the levels at 4300.86, 5269.0, and 5348.6 keV.

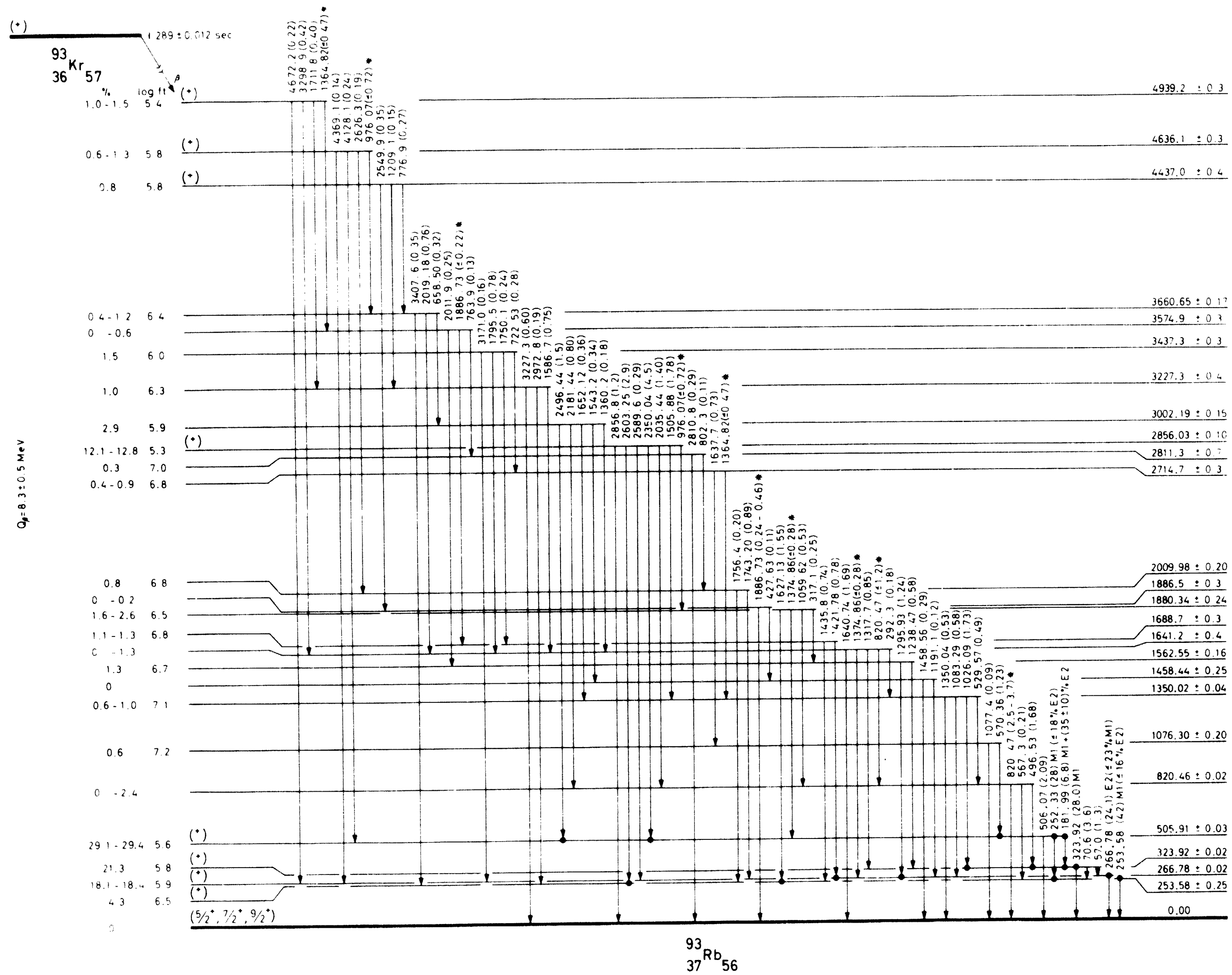

FIG. 6. Level scheme for ^{93}Rb. Transition intensities per 100 disintegrations are given within parentheses. Coincidence relations are marked by dots. Doubly placed γ rays are marked with asterisks. Q_B and $T_{1/2}$ of ^{93}Kr were taken from Refs. 4 and 3, respectively. β^- feeding intensity ranges were calculated as described in Sec. IV.

Comparison with the results of Ref. 9. Herzog and Grimm proposed for the ^{93}Sr ground state $J^\pi = \frac{5}{2}^+$, on the basis of logft values. However, using only their logft values and following strictly the criteria[25,26] accepted for the assignment of spins and parities from such values, we obtain $\frac{5}{2}^\pm$, and $\frac{7}{2}^+$ as the only possibilities for the mentioned ground state. Furthermore, Herzog and Grimm omit use of the logft value of the β feeding to the 758.63-keV level in ^{93}Y, which has a well established $J^\pi = \frac{9}{2}^+$. From their γ intensities, we calculate a β feeding to this level of 5.3 per hundred disintegrations and a corresponding logft value of 7.4 (logf_1t = 8.9). Combining the J^π values deduced earlier with the ones obtained using this logft, a $\frac{5}{2}^-$, $\frac{7}{2}^+$ assignment follows for the ^{93}Sr ground state, in complete agreement with the assignment proposed in the present work.

C. Scheme of ^{93}Rb

1. Level energies

The proposed level scheme of ^{93}Rb is shown in Fig. 6. It contains 76 transitions (97% of the total observed γ intensity) within a frame of 26 levels.

The levels at 253.58, 266.78, 323.92, 505.91, 820.46, 1076.30, 1350.02, 1562.55, 1688.7, 1880.34, 2856.03, and 3002.19 keV are supported by $\gamma\gamma$ coincidences, energy sums, and intensity balances. For the level at 2714.7 keV there is an indirect coincidence (see Table VII) that supports its location. The 12 remaining excited levels have been constructed on the basis of energy combinations and intensity balances. All of them are connected to other levels by at least three transitions.

We were able to show that the 57 ± 15-μsec isomeric level proposed by Grüter *et al.*[5,7] in ^{93}Rb is populated in the decay of ^{93}Kr by less than 0.05% of the disintegrations of the parent, by searching for the 830-keV γ ray deexciting it.

2. Discussion of spin-parity assignments

Results based on strong arguments. The excited levels at 253.58, 266.78, and 323.92 keV in ^{93}Rb have the same parity as the ground state according to the multipolarities we determined for the transitions of these energies. The multipolarities of the 181.99- and 323.92-keV transitions allow us to establish that the 505.91-keV level also has the same parity as the ground state.

In view of the allowed character of the β feeding to the 505.91- and 323.92-keV levels, the parity of the ^{93}Kr ground state is also the same as the parity of the ^{93}Rb ground state. Consequently, the β transitions that populate the 253.58- and 266.78-keV levels, with logft values 6.5 and 5.9, respectively, have allowed character. Furthermore, as the logft values of the β transitions that populate the levels at 2856.03, 4437.0, 4636.1, and 4939.2 keV show an allowed character, the parity of these levels is the same as that of the ground state of ^{93}Kr and ^{93}Rb.

The logft value obtained for the ^{93}Rb to ^{93}Sr ground-state β branch determines the possibilities $\Delta J = 0, \pm 1$.

Results based on weak arguments. For the β decay from the ^{93}Rb ground state to the ^{93}Sr ground state, we determined a logft value of 5.85 ± 0.03, and thus, conforming to the criteria given in Ref. 26, the transition is allowed. In view of the proximity of the limit given in Ref. 26 for the first-forbidden nonunique transitions (5.9) we prefer to use our logft value only as a weak argument for the parity assignment in this case. On this basis, we restricted the possible J^π assignments for the ^{93}Rb ground state to ($\frac{5}{2}^+$, $\frac{7}{2}^+$, $\frac{9}{2}^+$), whence follow the tentative positive parities of the ^{93}Kr ground state and the ^{93}Rb excited levels shown in Fig. 6.

V. CONCLUSIONS

Our results show that the ground states of ^{93}Kr and ^{93}Rb have the same parity. This fact cannot be accounted for on the basis of the spherical single-particle model, and contradicts the trend suggested by the systematics.

The possible spin-parity values of $\frac{5}{2}^-$, $\frac{7}{2}^+$ obtained by us for the ^{93}Sr ground state disagree with the rather scarce systematics of odd-A, $N > 50$, Sr isotopes, which suggests $\frac{5}{2}^+$.

As regards the proposed level scheme for ^{93}Rb it is seen that it does not fit the spherical single-particle model predictions, by showing a rather high level density at low energies, and that these levels are connected by $M1$ transitions.

Even though no conclusive evidence was found to affirm the existence of deformations in the nuclei studied, at least the case of ^{93}Rb appears as a likely prospect. In view of the deformation zone suggested in Ref. 2, it should be noted that the present work in this sense complements the conclusions arrived at in Achterberg *et al.*[1] for the existence of deformations in the case of ^{91}Rb.

It would appear desirable, in view of the results obtained in these two works, to extend this type of study to other isotopes in the zone proposed in Ref. 2, specially those of the 95 mass chain.

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