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Level schemes of ^{91}Rb and ^{91}Sr populated in beta decay*

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The decays of mass-separated ^{91}Kr and ^{91}Rb have been studied using γ-ray singles and coincidence techniques. From the decay of ^{91}Kr, a level scheme is proposed for ^{91}Rb consisting of 60 excited states and accommodating 218 of the 220 observed transitions. The half-life of the 108.8-keV level of ^{91}Rb has been determined to be 0.8 ± 0.3 nsec by delayed coincidence techniques. From the decay of ^{91}Rb, 109 of the 125 observed transitions are placed in a level scheme for ^{91}Sr containing 37 excited states. The half-life of the 93.6-keV level in ^{91}Sr has been measured to be 87.5 ± 3.0 nsec. Ground-state β branching has been determined to be $(10\pm4)\%$ and $(5\pm5)\%$ for the decays of ^{91}Kr and ^{91}Rb, respectively. Some spin-parity assignments are made, and a shell-model interpretation is suggested for some of the levels.

[RADIOACTIVITY ^{91}Kr, ^{91}Rb [from ^{235}U(n,f)]; measured E_γ, I_γ, γ-γ coin, delayed coin, deduced g.s. β branch, logft. ^{91}Rb, ^{91}Sr deduced levels, J, π, $T_{1/2}$. Mass-separated ^{91}Kr activity.]

I. INTRODUCTION

The proximity of the odd nuclei ^{91}Rb and ^{91}Sr to the shell-model configuration closures at $Z=38$ and $N=50$ makes the study of their structures of interest, especially in view of recent suggestions that deformation may be present in this region (see Ref. 1). The decays of ^{91}Kr and ^{91}Rb have been studied as a part of the continuing program at the TRISTAN facility using on-line isotope separation techniques. The decay of ^{91}Sr at this facility has already been reported, including a study of its β-ray spectra.[2,3] Because of their complexity, the decays of ^{91}Kr and ^{91}Rb have required a study period of considerable length; while the results of this work were in very preliminary form, the apparently concurrent study of Achterberg *et al.*[1] appeared in print, and we were compelled to reexamine some of the features of this work which preliminarily were in conflict with those reported in Ref. 1.

The first identification of the decays of ^{91}Kr and ^{91}Rb was made by Kofoed-Hansen and Nielsen in 1951.[4] Subsequent studies were reported by Wahl *et al.*,[5] Wahlgren and Meinke,[6] and Amarel *et al.*[7] Borg *et al.*[8] and Amiel *et al.*[9] reported energies for the prominent γ rays observed in the decay of ^{91}Kr using on-line techniques. The first decay scheme for ^{91}Kr was proposed by Eidens, Roeckl, and Armbruster[10] which included three levels with two connecting transitions, and 20% of the β decays populating the ground state of ^{91}Rb directly. Mason and Johns[11] later proposed a scheme for ^{91}Rb with four excited states involving six transitions. The latest reported level scheme[1] is considerably more comprehensive than the earlier ones, and has 31 levels with 94 connecting transitions. These authors also reported that the transition from the first excited state in ^{91}Rb to the ground state was parity changing, and they suggested an onset of deformation in the excited levels in ^{91}Rb to account for this event, unusual in this region of nuclei.

For the decay of ^{91}Rb, Malmskog and McDonald in 1969 reported three levels involving three connecting transitions,[12] while measuring the level lifetime of the first excited state in ^{91}Sr. The $E2$ character of the transition from this state was confirmed by Mason and Johns.[11] In the study by Mason and Johns, a level scheme for ^{91}Sr was presented which contained 18 levels to accommodate 28 transitions. The recent work of Achterberg *et al.*[1] presents a level scheme of 16 levels and 39 transitions.

The work on these decays at the TRISTAN facility has proceeded from a variety of measurements. The half-lives of ^{91}Kr and ^{91}Rb were first determined to be 8.57 ± 0.04 sec and 58.2 ± 0.2 sec, respectively.[13] The decay energies were measured by β-γ coincidence techniques to be 6.12 ± 0.07 MeV and 5.68 ± 0.04 MeV, respectively.[14] Finally, while this work was in its final stages, the internal conversion coefficients for the dominant low-energy transitions in both decays were measured by Wohn *et al.*[15] The latter results were in direct contradiction with the nature of the low-lying excited level structure of ^{91}Rb suggested by Achterberg *et al.* and indicate that there is no experimental confirmation of the suggestion that deformation is present in the structure of ^{91}Rb. The results of the γ-ray studies at TRISTAN are reported in this work, and represent a considerable extension of the previous reported studies, including the relatively comprehensive work reported in Ref. 1.

II. EXPERIMENTAL TECHNIQUES

A. Sample preparation

The TRISTAN on-line isotope separator facility[16] was used to provide the mass-separated fission product activity ^{91}Kr, and its daughter activity ^{91}Rb, for this study. Briefly, a sample of about 10 g of ^{235}U stearate is placed in a neutron beam of a flux 3×10^9 neutrons/cm^2 sec. The inert gaseous fission products emanating from the sample are transported to the isotope separator ion source through a line of about 1.6-m length. The mass-separated ion beam is deposited on an aluminized Mylar tape in a moving tape collector, which is used to enhance either the parent or the daughter activity. Compared to the equilibrium activity, the enhancement factors were 20 for the decay of ^{91}Kr and 100 for the decay of ^{91}Rb, making possible the unambiguous identification of the transitions observed. Slight amounts of contamination were usually seen from the ion-hydride $A = 90$ activities and ^{41}Ar (from the reactor).

B. Data accumulation and analysis

The γ-ray spectra were obtained in singles and coincidence modes using two Ge(Li) detectors having approximately 10% efficiency and 2.5-keV resolution at 1332 keV. For coincidence studies, the data were taken in a 4096×4096 pairwise format at a 180° geometry and with a 40 nsec timing window. They were then sorted event by event at the Iowa State University Computation Center. Low-energy singles spectra were measured using a 1-cm^3 Ge(Li) low energy photon spectrometer (LEPS) having a resolution of 500 eV at 122 keV. Delayed-coincidence time spectra were recorded from a LEPS-plastic scintillator combination, previously described by Morman, Schick, and Talbert,[17] in a two-parameter format identical to that used in γ-γ coincidence studies.

Peak centroids and areas were determined from the singles γ-ray spectra using the program SKEWGAUS.[18] Energy calibration, efficiency calibration, and energy nonlinearity were determined using sources of ^{56}Co, ^{57}Co, ^{60}Co, ^{133}Ba, ^{137}Cs, ^{182}Ta, ^{192}Ir, and ^{226}Ra. The calibration energies used were weighted averages of those reported by Greenwood and co-workers[19–21] and Multhauf and Tirsell.[22] Calibration intensities were adapted from Gunnick *et al.*,[23] Camp and Meredith,[24] Aubin *et al.*,[25] Henry,[26] and Edwards *et al.*[27]

Approximately 14×10^6 and 7×10^6 coincidence events were sorted using 84 and 42 gates for ^{91}Kr and ^{91}Rb decays, respectively. Adjacent "background" coincidence spectra were determined for each gate. The resulting spectra were analyzed both visually and quantitatively to construct and verify the proposed decay schemes.

The level schemes were constructed using energy sum and difference relationships as well as coincidence information. The level energies were determined from a weighted average of all transition energies into and out of each level. A confidence index (CI) was established as a criterion for proposed new levels. For a particular level, the CI is given by $N_p + N_d + 2N_{dc} + N_{pc}$, where N_p and N_d represent the number of transitions populating and depopulating a level and N_{dc} and N_{pc} are the respective number of definite and possible coincidences associated with the level. With a few exceptions, levels were required to have CI > 3 to be incorporated into the level scheme.

Ground-state β branchings in the decays of ^{91}Kr and ^{91}Rb were deduced from singles γ-ray spectra accumulated during partial equilibrium decay conditions (the decay chain activities of ^{91}Kr and ^{91}Rb in decay equilibrium with ^{91}Sr "growing in"). After accumulation of four γ-ray spectra during a period of 2 h in which the activity was appropriately monitored for the constant deposition condition, the deposition of ^{91}Kr was halted and the collected source allowed to decay. This decay was monitored for several hours in the accumulation of successive ^{91}Sr spectra. These spectra, with appropriate corrections for the 9.48-h half-life of ^{91}Sr, allowed the determination of the intensities of ^{91}Kr and ^{91}Rb transitions relative to those in ^{91}Sr decay. Since the ground-state β branch in the decay of ^{91}Sr is known,[3] those of the decays of ^{91}Kr and ^{91}Rb could then be deduced from the relative γ-ray intensities (corrected for internal conversion[15]). Finally, the absolute β branchings and log*ft* values were calculated for each level scheme.

III. EXPERIMENTAL RESULTS

A. Decay of ^{91}Kr

An enhanced γ-ray spectrum of the decay of ^{91}Kr is shown in Fig. 1. Of the 220 transitions listed in Table I, less than half have been reported in pre-

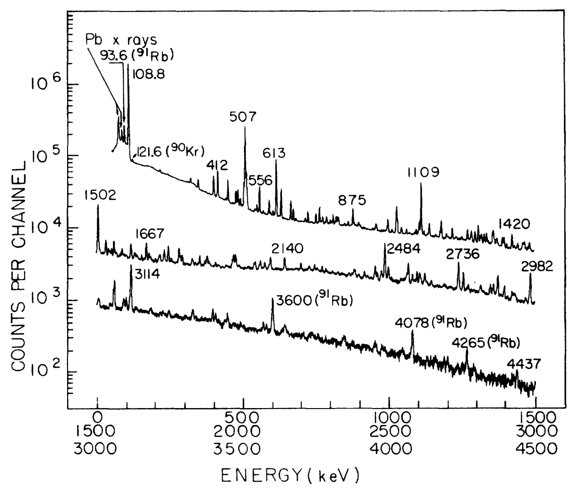

FIG. 1. ^{91}Kr-enhanced γ-ray spectrum.

vious studies.[1,11] The relative intensities resulting from this work are at variance with those reported by Achterberg *et al.*[1] as shown in Table II. The variance is at least partly accounted for by the difficulty of analyzing the peak at 108.8 keV, which happens to serve as the normalizing transition and is difficult to fit due to the shape of the background beneath it. A number of independent measurements using the Ge(Li) and LEPS detectors and measurements by Weinbeck[28] and Wohn *et al.*[29] at this laboratory have resulted in relative intensities consistent with those reported in Table I. The discrepancy between laboratories is not understood, and so we have been especially careful in the collection and evaluation of our data. Typical LEPS spectra are not presented here, but can be seen in Ref. 15. Also, multiplets have been observed at 822-825, 953-955, 1025-1028, 1354-1356, 1456-1459, 1555-1557, 1725-1728, and 2555-2558-2559 keV in our data. In the case of multiplets unresolved in singles spectra, coincidence intensities were used to apportion the intensities of components placed in different places in the decay scheme on the basis of the coincidence results.

The level scheme developed for ^{91}Rb on the basis of the singles and coincidence information is shown in Fig. 2. This level scheme accommodates 218 of the 220 transitions in 60 excited levels. Coincidence relations are noted on the level scheme; a detailed tabulation of the coincidence results is not presented here in the interest of brevity, but is available in Glascock.[30] Transition intensities are indicated per 100 decays. The dashed levels were established on the basis of only a single coincidence or fewer than three transitions (in which case CI $\leq$ 3).

The β branch to the ground state of ^{91}Rb was determined to be $(8\pm 5)\%$, on the basis of the relative equilibrium γ-ray intensities. Preliminary results from a direct measurement of the ground-state β branching by Wohn *et al.*[29] using a 4π β counter indicate a $(12\pm 5)\%$ ground-state branch. A weighted average value of $(10\pm 4)\%$ was thus used in this work. This value is in sharp disagreement with the $(20\pm 2)\%$ value of Achterberg *et al.*,[1] possibly due to the differences in relative γ-ray transition intensities and the presence of the many additional transitions reported in this work.

Intensity balances to all excited states and the ground-state β branching were used to calculate the absolute β branchings and $\log ft$ values presented in Table III. The intensity balances were corrected for internal conversion (the 108.8-keV transition dominated this correction, with a total conversion coefficient of 0.115 ± 0.007, taken from the K-shell coefficient of Ref. 15).

The half-life of the 108.8-keV level of ^{91}Rb is too short to be determined by fitting the slope of the LEPS-plastic delayed coincidence curve. However, the coincidence time peak centroid shift yielded a value of 0.8 ± 0.3 nsec, consistent with the expected value for an $M1$ transition.

B. Decay of ^{91}Rb

An enhanced γ-ray spectrum from the decay of ^{91}Rb is shown in Fig. 3. In this spectrum, 125 transitions were observed as listed in Table IV, considerably more than reported earlier for this decay.[1,11] As in the ^{91}Kr decay, the intensities reported in Table IV are at variance with those of Achterberg *et al.*,[1] and also with those of Mason and Johns.[11] A comparison of the intensities of major transitions is presented in Table V. Again, the normalization transition at 93.6 keV has an irregular background beneath it which makes an area determination difficult. Extreme care was taken in the determination of the intensities reported in this work, including many independent measurements using Ge(Li) and LEPS detectors, combined with independent measurements by Weinbeck[28] and Wohn *et al.*[29]

Transitions reported by Achterberg *et al.* at 2331, 2424, 2714, and 3334 keV were found in this work to be due entirely to escape peaks. Multiplets at 1624-1625-1628, 3600-3604, 3639-3644, and 3736-3746 keV were resolved in this work.

In the analysis of the coincidence spectra, several weak transitions were not observed in the 93.6-keV gate due to the large conversion coefficient and the long lifetime of the 93.6-keV level.

TABLE I. γ rays observed in the decay of ^{91}Kr.

Energy (keV)	Relative intensity [a]	Placement	Energy (keV)	Relative intensity [a]	Placement
108.78 ±0.04	1000 ±58.	108- 0	1091.61 ±0.14	7.9 ± 0.7	2593-1501
215.46 ±0.22	4.1 ± 0.8	721- 506	1102.18 ±0.15	17.4 ± 1.8	1211- 108
384.3 ±0.4	1.5 ± 0.6	3113-2729	1108.68 ±0.10	165 ± 9	1615- 506
397.83 ±0.13	36.0 ± 2.5	506- 108	1129.8 ±0.6	2.5 ± 0.9	3974-2844
400.7 ±0.3	4.9 ± 1.2	2490-2089	1136.81 ±0.14	23.8 ± 1.9	1136- 0
412.04 ±0.08	54 ± 3	1133- 721	1158.8 ±0.7	2.4 ± 1.1	1267- 108
446.78 ±0.06	38.0 ± 2.0	555- 108	1178.03 ±0.11	29.6 ± 1.6	1178- 0
450.8 ±0.4	1.2 ± 0.4	1775-1324	1195.42 ±0.20	6.0 ± 0.6	1304- 108
470.0 ±0.5	1.5 ± 0.5	2559-2089	1198.9 ±0.5	2.2 ± 0.6	2377-1178
474.63 ±0.10	21.0 ± 1.4	2089-1615	1202.2 ±0.4	2.7 ± 0.6	4129-2926
481.39 ±0.09	28.5 ± 1.9	1615-1133	1215.57 ±0.14	15.2 ± 1.2	1324- 108
489.49 ±0.15	9.9 ± 1.3	1211- 721	1227.49 ±0.22	2.8 ± 0.5	4072-2844
501.97 ±0.12	37 ± 6	502- 0	1231.1 ±0.3	1.2 ± 0.5	3206-1975
506.58 ±0.07	440 ±30	506- 0	1247.4 ±0.4	4.0 ± 1.0	4211-2964
541.9 ±0.9	1.3 ± 0.7	2089-1547	1267.83 ±0.13	15.3 ± 1.1	1267- 0
545.96 ±0.11	9.4 ± 0.8	1267- 721	1277.0 ±0.4	4.8 ± 0.8	1778- 502
555.57 ±0.07	44.7 ± 2.4	555- 0	1281.11 ±0.15	14.2 ± 1.1	2002- 721
569.00 ±0.19	4.7 ± 0.6	4543-3974	1292.95 ±0.17	11.2 ± 1.2	1401- 108
588.22 ±0.07	20.7 ± 1.2	2089-1501	1304.28 ±0.13	28.8 ± 1.9	1304- 0
612.87 ±0.06	177 ± 9	721- 108	1311.34 ±0.21	10.2 ± 1.2	3090-1778
630.14 ±0.07	51 ± 3	1136- 506	1315.54 ±0.17	13.5 ± 1.3	2037- 721
662.42 ±0.07	29.4 ± 1.8	662- 0	1324.22 ±0.18	12.6 ± 1.2	1324- 0
671.46 ±0.08	16.2 ± 1.2	1178- 506	1327.3 ±0.6	3.0 ± 0.9	2964-1637
680.0 ±0.3	2.7 ± 0.7	1401- 721	1338.0 ±0.4	4.0 ± 0.8	3113-1775
712.39 ±0.15	5.1 ± 0.6	1267- 555	1353.54 ±0.21	13.8 ± 2.0	2490-1136
721.55 ±0.08	15.2 ± 1.0	721- 0	1356.17 ±0.18	17.2 ± 2.0	2490-1133
748.64 ±0.08	13.1 ± 0.9	1304- 555	1359.63 ±0.22	5.0 ± 1.1	2861-1501
761.01 ±0.08	23.9 ± 1.5	1267- 506	1365.3 ±0.5	5.3 ± 1.3	3002-1637
766.0 ±0.9	1.2 ± 0.7	1267- 502	1368.5 ±0.3	7.7 ± 1.3	2089- 721
771.86 ±0.16	8.0 ± 0.9	2861-2089	1386.99 ±0.17	12.6 ± 1.3	3002-1615
780.2 ±0.6	2.4 ± 0.9	1501- 721	1392.74 ±0.17	12.6 ± 1.2	1501- 108
785.25 ±0.16	10.7 ± 1.2	2089-1304	1402.0 ±0.3	5.2 ± 1.1	1401- 0
797.68 ±0.15	5.6 ± 0.6	1304- 506	1419.72 ±0.13	19.4 ± 1.3	1975- 555
802.17 ±0.15	2.8 ± 0.5	1304- 502	1426.1 ±0.6	2.4 ± 0.8	2559-1133
807.14 ±0.09	13.2 ± 0.9	2844-2037	1439.11 ±0.21	8.3 ± 0.9	1547- 108
814.0 ±0.4	3.0 ± 0.7	2593-1778	1456.5 ±0.5	8.1 ± 2.3	2593-1136
817.64 ±0.18	10.6 ± 1.0	1324- 506	1459.0 ±0.7	6.5 ± 1.8	2593-1133
822.14 ±0.18	9.1 ± 0.9	2089-1267	1468.2 ±0.6	3.7 ± 0.9	1975- 506
825.82 ±0.16	9.4 ± 0.9	1547- 721	1474.6 ±0.5	2.0 ± 0.6	2195- 721
846.7 ±0.4	2.5 ± 0.8	1401- 555	1479.90 ±0.21	12.4 ± 1.4	4698-3218
858.68 ±0.22	5.9 ± 1.0	2861-2002	1500.6 ±0.5	16.0 ± 2.0	3002-1501
874.92 ±0.08	29.3 ± 1.6	2490-1615	1501.60 ±0.11	111 ± 7 [b]	1501- 0
879.5 ±0.3	2.9 ± 0.5	2381-1501	1506.4 ±0.4	19 ± 4	1615- 108
893.6 ±0.4	4.0 ± 1.0 [b]	1615- 721	1517.8 ±0.5	2.0 ± 0.6	2729-1211
895.0 ±0.5	6.6 ± 1.5 [b]	1401- 506	1525.0 ±0.5	3.7 ± 0.9	2926-1401
900.5 ±0.4	3.6 ± 0.9	2037-1136	1528.29 ±0.14	20.9 ± 1.4	1687- 108
953.24 ±0.16	7.6 ± 0.8	2089-1136	1537.34 ±0.24	7.6 ± 1.0	2861-1324
955.74 ±0.16	7.3 ± 0.8	2089-1133	1547.65 ±0.25	8.4 ± 1.1	1547- 0
992.1 ±0.6	2.9 ± 1.1	1547- 555	1555.3 ±0.4	14 ± 4	3056-1501
995.08 ±0.12	18.4 ± 1.3	1501- 506	1557.2 ±0.5	11 ± 4	2861-1304
1008.98 ±0.23	4.3 ± 0.7	3046-2037	1563.6 ±0.4	4.0 ± 0.8	4543-2979
1024.91 ±0.15	66 ± 5	1133- 108	1577.6 ±0.6	2.2 ± 0.7	2979-1401
1028.3 ±0.3	15 ± 3	1136- 108	1583.51 ±0.19	8.8 ± 0.8	2089- 506
1041.80 ±0.15	5.0 ± 0.6	3044-2002	1589.2 ±0.5	2.5 ± 0.7	3090-1501
1058.90 ±0.15	6.2 ± 0.6	2195-1136	1614.07 ±0.14	23.8 ± 1.7	1722- 108
1069.0 ±0.3	2.0 ± 0.5	1178- 108 [c]	1626.7 ±0.4	7.5 ± 2.2	4683-3056
1085.9 ±0.3	2.7 ± 0.5	4199-3113	1633.5 ±0.7	3.3 ± 2.5	2844-1211

TABLE I (*Continued*)

Energy (keV)	Relative intensity [a]	Placement	Energy (keV)	Relative intensity [a]	Placement
1650.22 ±0.24	3.9 ± 0.8	2861-1211	2539.4 ±0.3	3.9 ± 0.5	3046- 506
1659.4 ±0.5	2.4 ± 0.6	2964-1304	2550.6 ±0.4	4.2 ± 0.5	3056- 506
1666.73 ±0.13	6.2 ± 1.5 [b]	2844-1178	2555.8 ±0.6	2.2 ± 1.0 [b]	3218- 622
1666.73 ±0.13	18.1 ± 1.5 [b]	1775- 108	2558.0 ±0.4	4.0 ± 1.5 [b]	3113- 555
1675.83 ±0.19	8.8 ± 0.8	2979-1304	2559.4 ±0.4	8.1 ± 1.3 [h]	2559- 0
1681.2 ±0.3	4.0 ± 0.7	4683-3002	2585.6 ±0.5	2.3 ± 0.6	3910-1324
1697.6 ±0.5	3.4 ± 1.1	3002-1304	2593.15 ±0.20	12.5 ± 1.2	2593- 0
1710.0 ±0.4	5.6 ± 1.8	3325-1615	2606.9 ±0.5	5.6 ± 1.1	3113- 506
1725.2 ±0.3	4.4 ± 1.0	2861-1136	2620.33 ±0.23	15.5 ± 1.4	2729- 108
1727.85 ±0.16	11.5 ± 0.9	2861-1133	2627.7 ±0.8	4.0 ± 0.5	4129-1501
1741.78 ±0.13	18.5 ± 1.4	2919-1178	2642.5 ±0.4	4.7 ± 0.8	3910-1267
1752.9 ±0.3	4.3 ± 0.7	2964-1211	2663.0 ±0.7	2.0 ± 0.6	3218- 555
1778.85 ±0.16	18.9 ± 1.5	1778- 0	2687.0 ±0.9	2.1 ± 1.0	2686- 0
1783.4 ±0.3	8.7 ± 1.1	2919-1136	2732.1 ±0.7	5.5 ± 1.7	3910-1178
1789.43 ±0.21	9.4 ± 1.0	3113-1324	2735.83 ±0.19	34 ± 3	2844- 108
1823.05 ±0.24	6.8 ± 0.8	3090-1267	2752.59 ±0.19	17.0 ± 1.4	2861- 108
1827.1 ±0.4	4.7 ± 0.9	2964-1136	2769.4 ±0.5	4.8 ± 1.2	3325- 555
1834.6 ±0.4	3.0 ± 0.6	4211-2377	2809.9 ±1.2	2.8 ± 1.6	4211-1401
1843.1 ±0.6	2.9 ± 0.8	2979-1136	2811.7 ±0.6	6.2 ± 0.7	2919- 108
1856.6 ±0.8	1.9 ± 0.8	4543-2686	2845.0 ±0.3	7.7 ± 1.2	2844- 0
1866.2 ±0.3	3.8 ± 0.8	1975- 108	2855.3 ±0.3	9.3 ± 1.2	2964- 108
1871.8 ±0.3	4.4 ± 1.3	2593- 721	2870.54 ±0.21	19.6 ± 1.7	2979- 108
1874.99 ±0.24	10.9 ± 1.4	2381- 506	2893.5 ±0.3	9.2 ± 1.1	3002- 108
1880.1 ±0.4	5.6 ± 1.0	3090-1211	2904.4 ±1.1	1.7 ± 0.9	4683-1778
1884.3 ±0.8	2.4 ± 0.4	3974-2089	2919.9 ±0.4	6.2 ± 1.0	2919- 0
1913.9 ±0.8	1.5 ± 0.7	3218-1304	2926.7 ±0.5	2.0 ± 0.7	2926- 0
1965.11 ±0.19	15.3 ± 1.4	2686- 721	2930.8 ±0.5	4.5 ± 1.0	4545-1615
1982.7 ±0.5	3.8 ± 0.9	2490- 506	2966.6 ±0.7	2.9 ± 0.8	3687- 721
1995.0 ±0.8	1.0 ± 0.5	3206-1211 [c]	2981.85 ±0.19	30.0 ± 1.9	3090- 108
2004.1 ±0.9	0.9 ± 0.9	2559- 555	3001.9 ±0.8	5.9 ± 2.1	3002- 0
2039.36 ±0.24	8.9 ± 1.0	4129-2089	3005.1 ±1.0	2.6 ± 1.9	3113- 108
2057.27 ±0.18	9.6 ± 0.8	2559- 502	3041.3 ±1.0	2.9 ± 1.3	4543-1501
2072.25 ±0.25	7.1 ± 1.0	3206-1133	3043.7 ±0.9	1.2 ± 1.1	3044- 0
2087.0 ±0.4	4.0 ± 1.0	2195- 108	3052.6 ±1.1	3.6 ± 1.9	
2139.98 ±0.21	16.4 ± 1.8	2861- 721	3056.80 ±0.22	20.0 ± 2.0	3056- 0
2195.99 ±0.23	8.1 ± 1.0	2195- 0	3097.4 ±0.3	8.4 ± 0.9	3206- 108
2242.50 ±0.25	3.9 ± 0.6	2964- 721	3109.6 ±0.5	8.3 ± 1.8	3218- 108
2251.4 ±0.5	3.3 ± 0.9	3974-1722	3113.50 ±0.20	49 ± 3	3113- 0
2268.6 ±0.4	5.2 ± 1.1	2377- 108	3180.9 ±0.8	2.5 ± 0.9	3687- 506
2281.1 ±0.6	3.4 ± 1.1	3002- 721	3265.4 ±1.0	1.4 ± 0.5	4569-1304
2322.6 ±0.8	2.5 ± 1.0	3044- 721	3324.9 ±0.4	5.0 ± 0.7	3325- 0
2377.34 ±0.23	8.2 ± 0.8	2377- 0	3393.6 ±0.3	6.5 ± 0.8	4698-1304
2381.87 ±0.24	5.0 ± 0.7	2381- 0	3403.4 ±0.5	3.7 ± 0.8	3910- 506
2391.8 ±0.9	2.6 ± 1.0	3113- 721	3435.7 ±1.0	2.2 ± 0.9	4569-1133
2395.1 ±0.7	3.0 ± 1.0	3056- 662	3444.4 ±0.5	4.9 ± 1.0	
2413.7 ±0.3	7.8 ± 1.1	2919- 506	3490.0 ±1.1	1.7 ± 0.8	4211- 721
2425.0 ±0.7	3.4 ± 1.0	2926- 502	3578.4 ±0.5	2.5 ± 0.6	3687- 108
2447.3 ±0.7	5.7 ± 1.6	3002- 555	3705.0 ±1.1	1.5 ± 0.6	4211- 506
2450.7 ±0.3	15.6 ± 1.9	2559- 108	3910.0 ±1.1	1.1 ± 0.4	3910- 0
2457.7 ±0.3	8.1 ± 1.2	2964- 506	3973.9 ±1.0	1.1 ± 0.4	3974- 0
2473.1 ±0.5	9.4 ± 2.0	2979- 506	4129.3 ±1.0	1.2 ± 0.4	4129- 0
2480.0 ±0.7	4.9 ± 1.4	4569-2089	4199.6 ±0.8	1.7 ± 0.5	4199- 0
2484.35 ±0.13	64 ± 4	2593- 108	4436.8 ±0.6	1.6 ± 0.3	4545- 108
2495.82 ±0.22	15.9 ± 1.5	3002- 506			

[a] The relative intensity can be converted to transitions per 100 β decays using the factor 0.0432, assuming a 10% β branch to the ground state of ^{91}Rb.

[b] Individual intensities split as determined from coincidence data.

[c] Denotes transition identified only in coincidence.

TABLE II. Comparison of major γ-ray intensities with prior ^{91}Kr studies.

Energy (keV)	This work	Achterberg *et al.*
108.78	1000 ± 58	1000 ± 100
506.58	440 ± 30	400 ± 60
612.87	177 ± 9	150 ± 16
1108.68	165 ± 9	164 ± 16
1501 (doublet)	127 ± 8	151 ± 16
2484.35	64 ± 4	72 ± 8
3113.50	49 ± 3	57 ± 6

The 510-keV transition was observed in the 1337-keV gate, and transitions at 3395, 3446, 3736, 4043, 4078, 4157, 4249, 4254, and 4265 keV were not seen in the coincidence profiles, an indication that they are transitions directly to the ground state.

The level scheme proposed for ^{91}Sr is shown in Fig. 4, and has 37 excited states involving 109 of the 125 observed transitions. In the equilibrium experiment, a ground-state β branch for the decay of ^{91}Rb was deduced to be (5± 5)%. The direct measurement of Wohn *et al.*[29] yielded a preliminary value of an upper limit of 6%. An averaged value of (5± 5)% was used in the determination of absolute β branches and logft values to the levels of ^{91}Sr, as listed in Table VI. This ground-state β branching is in very serious disagreement with earlier reports of (60± 10)% in Ref. 1 and 30% in Ref. 31. The magnitude of the discrepancy cannot be attributed to the γ-ray transition relative intensity differences or decay scheme refinements from the present work; its origin remains unexplained. In the level intensity balance determinations, a conversion coefficient of 1.30± 0.11 was used for the $E2$ 93.6-keV transition.[15]

The delayed coincidence time spectrum for the 93.6-keV transition with a fitted function is shown in Fig. 5. A half-life of 87.5± 3.0 nsec was found, in good agreement with previous measurements.[1,11,12] The $E2$ 93.6-keV transition in ^{91}Sr shows an enhancement of 16 relative to the Weisskopf estimate, using this half-life and the above-quoted total conversion coefficient.

IV. DISCUSSION

The level schemes proposed in this work for ^{91}Rb and ^{91}Sr show scarce resemblance to those proposed in Ref. 1, except for the first few excited states. In addition, as was pointed out in Ref. 15, the first excited state of ^{91}Rb must have the same parity as the ground state, contrary to the proposition of Ref. 1. The discussion of the level structures of these two nuclei depends wholly upon the decay data presented; no reaction studies have been made to date.

A shell-model basis for the description of these nuclei is formed conveniently, relative to a core nucleus of ^{88}Sr. In this basis, proton states available are the $p_{3/2}$ and $f_{5/2}$ hole states and the $p_{1/2}$ and $g_{9/2}$ particle states. The neutron configurations are constructed from the $d_{5/2}$, $s_{1/2}$, $d_{3/2}$, and $g_{7/2}$ states. The dominant ground-state configurations should be $\pi(p_{3/2})^{-2}\nu(d_{5/2})^5$, $\pi(p_{3/2})^{-1}\nu(d_{5/2})^4$, and $\nu(d_{5/2})^3$ for ^{91}Kr, ^{91}Rb, and ^{91}Sr, respectively. These expected configurations are consistent with the experimental facts: The ground-state spin-parity of ^{91}Sr has been determined to be $\frac{5}{2}^+$, from the first forbidden unique character of the β branch to the $\frac{1}{2}^-$ ground state of ^{91}Y.[3,32] The logft values for the ground-state β branches of both the ^{91}Kr and ^{91}Rb decays are consistent with a first forbidden nonunique character, as expected from the suggested configurations. Furthermore, the systematics of odd Rb nuclear structures present strong indication for a ground-state spin-parity of $\frac{3}{2}^-$ at ^{91}Rb (see Fig. 6). The following discussion will then proceed assuming that the ground-state assignments for the $A=91$ decay chain nuclei are those predicted by the shell-model configurations above. Logft values from β branches are useful in the discussion, following the rules of Raman and Gove.[38]

A. ^{91}Rb levels

Given the postulated spin-parity for the ground state of ^{91}Rb of $\frac{3}{2}^-$, the $M1$ multipolarity for the 108.8-keV transition, the logft value for the β branch to the 108.8-keV level, and the systematics of the first excited state in odd Rb isotopes, we assign a spin-parity of $\frac{5}{2}^-$ to the 108.8-keV level. If this level were to have a shell-model configuration of $\pi(f_{5/2})^{-1}\nu(d_{5/2})^4$, the 108.8-keV transition would be l forbidden. Such transitions have been observed,[39] although an alternative explanation in the transition strength would be inclusion of a minor admixture of the seniority-3 coupling for the ground-state configuration.

As is noted in Fig. 6, the $\frac{1}{2}^-$ (presumably $p_{1/2}$ particle) state progresses toward the $\frac{3}{2}^-$ ground state as the neutron number is increased beyond $N=50$. Such a state would be expected to deexcite directly to the ground state, and the 502.0-keV

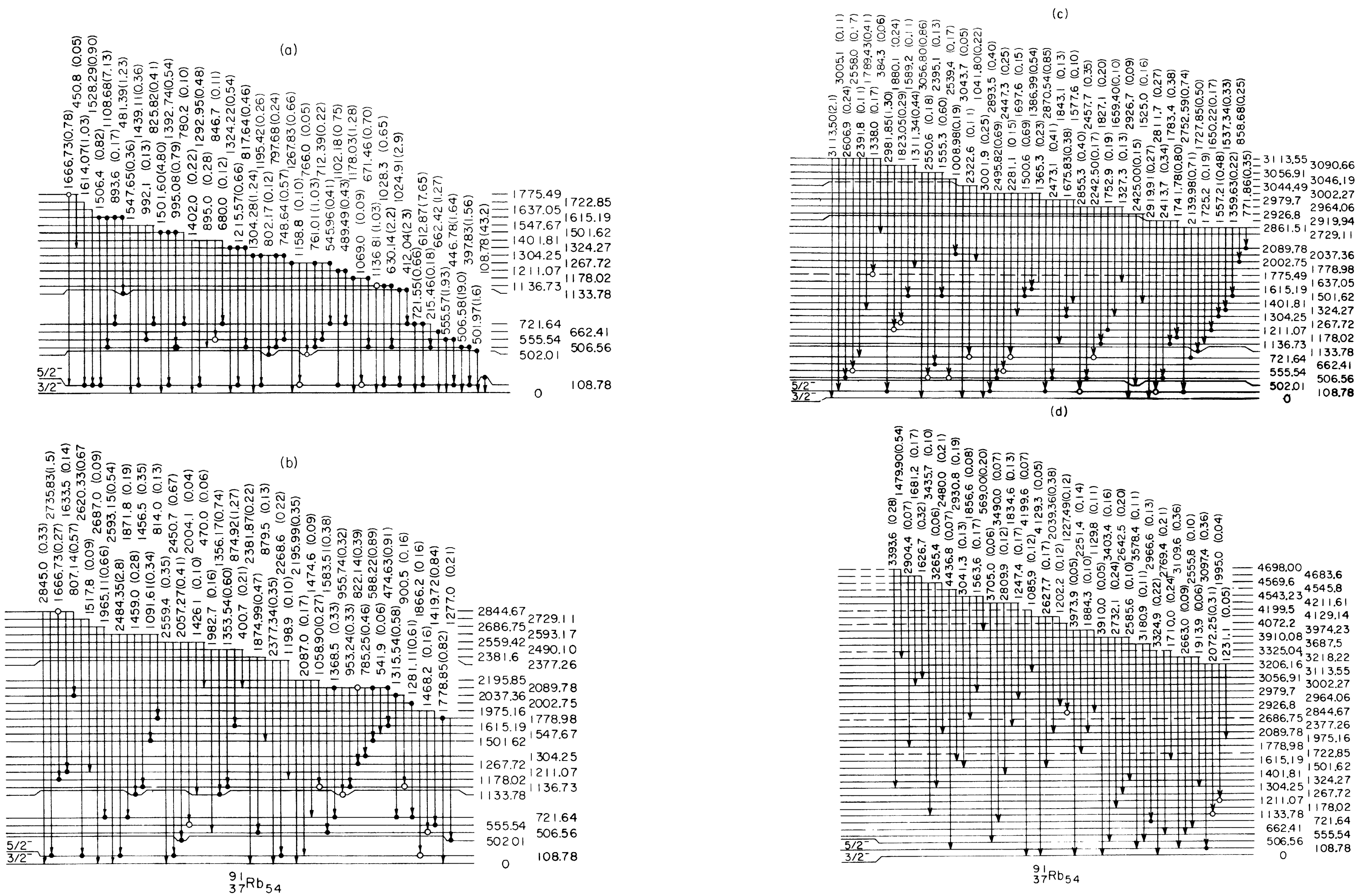

FIG. 2. Level scheme for ^{91}Rb populated in the decay of ^{91}Kr. Coincidences are indicated by filled (definite) or open (possible) circles at the transition start and termination points: (a) levels up to 1775 keV, (b) levels from 1778 to 2844 keV, (c) levels from 2861 to 3113 keV, (d) levels from 3206 to 4698 keV.

TABLE III. Logft values and β branching for ^{91}Kr decay.

Level energy (keV)	Percent β branching	Logft	Level energy (keV)	Percent β branching	Logft
0.00 ± 0.00	10 ± 4	6.4 ± 0.2	2559.42 ± 0.18	1.64 ± 0.16	6.15 ± 0.05
108.78 ± 0.07	15.9 ± 3.0	6.18 ± 0.09	2593.17 ± 0.09	4.6 ± 0.4	5.59 ± 0.05
502.01 ± 0.09	0.7 ± 0.3	7.41 ± 0.18 [a]	2686.75 ± 0.22	0.67 ± 0.09	6.47 ± 0.07
506.56 ± 0.12	3.8 ± 1.3	6.67 ± 0.15 [a]	2729.11 ± 0.20	0.69 ± 0.08	6.44 ± 0.06
555.54 ± 0.09	0.98 ± 0.21	7.24 ± 0.10 [a]	2844.67 ± 0.14	2.55 ± 0.25	5.81 ± 0.05
662.41 ± 0.07	1.05 ± 0.12	7.17 ± 0.06 [a]	2861.51 ± 0.18	3.9 ± 0.4	5.61 ± 0.05
721.64 ± 0.14	0.6 ± 0.5	7.4 ± 0.4 [a]	2919.94 ± 0.20	2.04 ± 0.17	5.86 ± 0.05
1133.78 ± 0.13	1.6 ± 0.3	6.80 ± 0.09 [a]	2926.8 ± 0.3	0.27 ± 0.07	6.73 ± 0.12
1136.73 ± 0.17	1.3 ± 0.3	6.90 ± 0.10 [a]	2964.06 ± 0.17	1.37 ± 0.14	6.01 ± 0.06
1178.02 ± 0.09	0.66 ± 0.15	7.17 ± 0.10 [a]	2979.7 ± 0.3	1.68 ± 0.17	5.91 ± 0.06
1211.07 ± 0.17	0.32 ± 0.16	7.48 ± 0.22 [a]	3002.27 ± 0.18	3.2 ± 0.3	5.62 ± 0.05
1267.72 ± 0.14	1.59 ± 0.16	6.76 ± 0.05 [a]	3044.49 ± 0.19	0.37 ± 0.07	6.52 ± 0.09
1304.25 ± 0.13	0.46 ± 0.24	7.28 ± 0.22 [a]	3046.19 ± 0.19	1.47 ± 0.25	5.92 ± 0.08
1324.27 ± 0.12	0.77 ± 0.12	7.05 ± 0.07 [a]	3090.66 ± 0.23	2.38 ± 0.19	5.69 ± 0.05
1401.81 ± 0.18	0.84 ± 0.15	6.98 ± 0.08 [a]	3113.55 ± 0.12	3.3 ± 0.3	5.53 ± 0.05
1501.62 ± 0.11	2.9 ± 0.4	6.40 ± 0.07	3206.16 ± 0.17	0.76 ± 0.08	6.11 ± 0.06
1547.67 ± 0.18	1.19 ± 0.12	6.77 ± 0.05	3218.22 ± 0.22	< 0.18	> 6.72
1615.19 ± 0.08	6.2 ± 0.6	6.03 ± 0.05	3325.04 ± 0.23	0.66 ± 0.11	6.09 ± 0.08
1637.05 ± 0.15	0.55 ± 0.10	7.07 ± 0.08 [a]	3687.5 ± 0.5	0.34 ± 0.06	6.13 ± 0.09
1722.85 ± 0.15	0.89 ± 0.10	6.82 ± 0.06 [a]	3910.08 ± 0.24	0.75 ± 0.10	5.61 ± 0.07
1775.49 ± 0.13	0.66 ± 0.08	6.93 ± 0.06 [a]	3974.23 ± 0.23	0.20 ± 0.07	6.13 ± 0.17
1778.98 ± 0.18	0.38 ± 0.10	7.17 ± 0.12 [a]	4072.2 ± 0.3	0.12 ± 0.02	6.27 ± 0.10
1975.16 ± 0.15	1.11 ± 0.11	6.61 ± 0.05	4129.14 ± 0.23	0.73 ± 0.07	5.44 ± 0.06
2002.75 ± 0.14	0.14 ± 0.07	7.49 ± 0.21 [a]	4199.5 ± 0.3	0.19 ± 0.03	5.96 ± 0.09
2037.36 ± 0.17	< 0.08	> 7.81 [a]	4211.6 ± 0.3	0.56 ± 0.10	5.48 ± 0.09
2089.78 ± 0.18	2.75 ± 0.25	6.17 ± 0.05	4543.23 ± 0.24	0.58 ± 0.09	5.13 ± 0.08
2195.85 ± 0.20	0.87 ± 0.09	6.61 ± 0.06	4545.8 ± 0.4	0.26 ± 0.05	5.47 ± 0.09
2377.26 ± 0.17	0.54 ± 0.08	6.73 ± 0.07	4569.6 ± 0.5	0.37 ± 0.08	5.30 ± 0.18
2381.6 ± 0.3	0.81 ± 0.09	6.55 ± 0.06	4683.6 ± 0.3	0.57 ± 0.11	4.98 ± 0.10
2490.10 ± 0.18	2.98 ± 0.25	5.93 ± 0.05	4698.00 ± 0.23	0.81 ± 0.09	4.80 ± 0.07

[a] Logf_1t > 8.5, so first forbidden unique β transition not excluded.

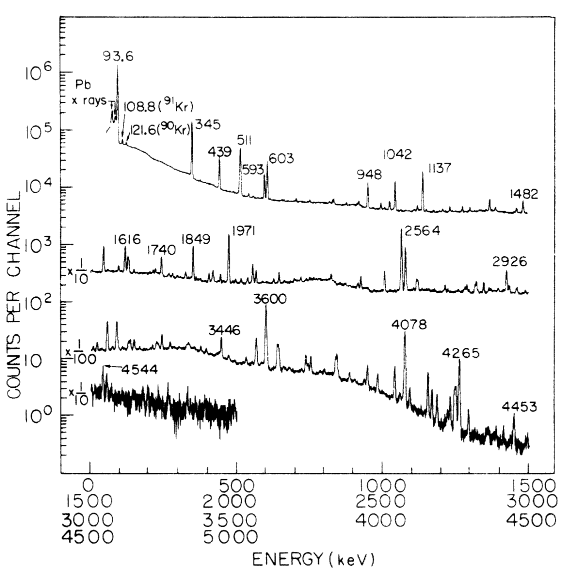

FIG. 3. ^{91}Rb-enhanced γ-ray spectrum.

level is a likely candidate for this particle excitation. The suggested configuration for this level would possibly be mixed with the $\frac{1}{2}^-$ state formed by coupling the ground-state configuration to components of the first excited state of the core nucleus ^{90}Kr (2^+ at 707 keV),[40] which would also have a dominant deexcitation to the ground state via the core. The 662.4-keV level may be a likely choice for this excitation by virtue of its energy and deexcitation pattern. A weak argument in support of the tentative assignments made to the 502.0- and 662.4-keV levels involves the paucity of transitions populating them from the other excited states, compared to the states around them. This suggests that they may have some unique character, which is certainly embodied in the suggested structures.

Unfortunately, even using the conversion electron measurements of Ref. 1 (which were shown to be incorrect in the case of the 108.8-keV transition[15]), the γ-ray branching patterns, and the

TABLE IV. γ rays observed in the decay of ^{91}Rb.

Energy (keV)	Relative intensity [a]	Placement (keV)
93.63 ± 0.02	1000 ± 51	93- 0
345.43 ± 0.03	246 ± 12	439- 93
439.15 ± 0.03	62 ± 3	439- 0
509.6 ± 0.5	5.1 ± 0.8	1740-1230 [b]
593.23 ± 0.03	38.2 ± 2.0	2657-2064
602.85 ± 0.03	84 ± 4	1042- 439
702.66 ± 0.25	3.1 ± 0.5	
749.73 ± 0.25	3.3 ± 0.6	4793-4043
816.5 ± 0.5	3.0 ± 0.7	
875.0 ± 0.3	3.2 ± 0.5	1917-1042
912.8 ± 0.4	2.1 ± 0.7	
917.59 ± 0.22	5.5 ± 0.9	2657-1740
948.49 ± 0.05	34.7 ± 1.9	1042- 93
993.69 ± 0.13	8.9 ± 0.8	4358-3364
1006.3 ± 0.4	2.8 ± 0.7	2236-1230
1023.20 ± 0.12	13.1 ± 1.1	2064-1042
1034.9 ± 0.6	3.9 ± 1.6	3693-2657
1041.99 ± 0.05	65 ± 3	1042- 0
1137.24 ± 0.05	115 ± 6	1230- 93
1149.7 ± 0.7	2.0 ± 0.8	4793-3643
1174.1 ± 0.5	2.9 ± 0.8	3831-2657
1205.6 ± 0.3	3.4 ± 0.7	3364-2159
1230.64 ± 0.15	8.7 ± 0.8	1230- 0
1238.7 ± 0.6	2.0 ± 0.6	
1250.7 ± 0.8	1.4 ± 0.6	
1274.05 ± 0.18	7.4 ± 0.9	1367- 93
1299.9 ± 0.3	4.8 ± 0.7	3364-2064
1367.76 ± 0.08	22.5 ± 1.5	1367- 0
1388.13 ± 0.24	6.5 ± 0.9	1482- 93
1482.17 ± 0.11	43 ± 3	1482- 0
1503.0 ± 0.7	2.7 ± 1.0	3446-1974
1594.15 ± 0.17	12.2 ± 1.1	3831-2236
1615.86 ± 0.09	73 ± 4	2657-1042
1624.8 ± 0.5	14.7 ± 1.0 [c]	3364-1740
1625.4 ± 0.3	21.2 ± 1.4 [c]	2064- 439
1628.49 ± 0.14	26.8 ± 1.7	3693-2064
1646.51 ± 0.23	7.7 ± 1.0	1740- 93
1712.0 ± 0.4	6.1 ± 1.2	3776-2064
1719.9 ± 0.3	9.1 ± 1.4	2159- 439
1740.25 ± 0.10	42 ± 3	1740- 0
1766.17 ± 0.18	4.9 ± 1.2	3831-2064
1794.5 ± 0.6	3.7 ± 1.1	4452-2657
1823.3 ± 0.4	10.6 ± 1.8	1917- 93
1841.1 ± 0.3	3.8 ± 1.3	4078-2236
1849.27 ± 0.09	98 ± 5	1942- 93
1859.56 ± 0.25	4.5 ± 0.9	3776-1917
1874.4 ± 0.4	3.3 ± 1.6	3938-2064
1917.11 ± 0.15	22.6 ± 1.7	1917- 0
1942.81 ± 0.17	11.8 ± 1.2	1942- 0
1953.0 ± 0.5	2.1 ± 0.9	3693-1740
1970.99 ± 0.10	199 ± 10	2064- 93
2013.5 ± 0.3	7.9 ± 1.2	4078-2064
2036.1 ± 0.3	10.9 ± 1.5	3776-1740
2064.69 ± 0.14	23.3 ± 1.8	2064- 0
2143.22 ± 0.14	19.8 ± 1.5	2236- 93
2161.8 ± 0.6	3.5 ± 1.1	3643-1482
2196.0 ± 0.4	5.5 ± 1.2	
2208.5 ± 0.7	3.1 ± 1.1	
2218.2 ± 0.3	8.3 ± 1.3	2657- 439
2236.9 ± 0.5	4.1 ± 1.0	2236- 0
2254.6 ± 0.4	3.7 ± 0.9	3736-1482
2263.1 ± 0.3	4.5 ± 0.9	4327-2064
2322.34 ± 0.21	13.3 ± 1.5	3364-1042
2448.5 ± 0.7	4.4 ± 1.4	4390-1942
2505.95 ± 0.14	42.2 ± 2.5	3736-1230
2564.19 ± 0.14	372 ± 19	2657- 93
2606.7 ± 0.5	4.1 ± 1.1	
2724.2 ± 0.7	5.1 ± 1.5	
2783.3 ± 0.4	9.9 ± 1.5	4265-1482
2789.6 ± 0.4	14.6 ± 1.5	4157-1367
2847.39 ± 0.22	19.3 ± 2.0	4078-1230
2872.5 ± 0.6	5.6 ± 1.7	4240-1367
2897.6 ± 0.5	6.1 ± 1.2	4265-1367
2912.0 ± 0.4	9.8 ± 0.7	
2925.72 ± 0.18	45 ± 3	3364- 439
2958.6 ± 0.6	3.8 ± 1.1	4189-1230
2990.6 ± 0.5	6.0 ± 1.5	4358-1367
3007.6 ± 0.5	8.1 ± 1.5	3446- 439
3107.9 ± 0.9	4.6 ± 1.6	
3147.30 ± 0.24	19.4 ± 1.9	4189-1042
3224.4 ± 0.3	9.7 ± 1.1	5289-2064
3270.9 ± 0.3	13.2 ± 1.8	3364- 93
3284.7 ± 0.8	4.8 ± 1.4	4327-1042
3302.2 ± 1.0	4.1 ± 1.6	3395- 93
3337.8 ± 0.5	6.5 ± 1.7	3776- 439
3346.2 ± 0.6	5.3 ± 2.4	5289-1942
3353.1 ± 0.6	6.0 ± 2.1	3446- 93
3376.5 ± 0.3	8 ± 4	
3395.4 ± 0.4	9.6 ± 1.7	3395- 0
3410.7 ± 0.8	2.4 ± 1.6	4452-1042
3446.50 ± 0.20	44 ± 3	3446- 0
3599.67 ± 0.19	309 ± 16	3693- 93
3604.3 ± 0.6	11 ± 5	4043- 439
3639.14 ± 0.22	36 ± 3	4078- 439
3643.75 ± 0.23	23.3 ± 2.3	3643- 0
3682.9 ± 0.7	2.4 ± 1.3	3776- 93
3736.5 ± 0.4	17 ± 4	3736- 0
3745.9 ± 0.5	6.0 ± 1.4	3839- 93
3800.7 ± 0.5	4.5 ± 1.0	4240- 439
3839.3 ± 0.3	18.2 ± 1.9	3839- 0
3844.33 ± 0.25	30.2 ± 2.5	3938- 93
3888.4 ± 0.4	8.4 ± 1.1	4327- 439
3906.2 ± 0.9	2.8 ± 0.9	
3938.7 ± 0.5	5.4 ± 1.1	3938- 0
3949.56 ± 0.23	19.1 ± 1.6	4043- 93
3984.7 ± 0.3	12.3 ± 1.3	4078- 93
4043.26 ± 0.22	22.0 ± 1.6	4043- 0
4061.3 ± 0.5	3.4 ± 1.2	
4063.9 ± 0.7	1.3 ± 0.9	4157- 93
4078.25 ± 0.19	121 ± 6	4078- 0
4095.7 ± 0.3	7.1 ± 0.9	4189- 93

TABLE IV *(Continued)*

Energy (keV)	Relative intensity [a]	Placement (keV)	Energy (keV)	Relative intensity [a]	Placement (keV)
4157.48 ± 0.22	20.8 ± 1.5	4157– 0	4265.45 ± 0.21	42.5 ± 2.5	4265– 0
4171.7 ± 0.3	8.3 ± 0.9	4265– 93	4297.1 ± 0.4	3.4 ± 0.5	4390– 93
4189.2 ± 0.3	6.9 ± 0.8	4189– 0	4357.9 ± 0.7	1.6 ± 0.5	4358– 0
4224.8 ± 0.6	3.0 ± 0.6		4391.3 ± 0.9	1.6 ± 0.5	4390– 0
4234.1 ± 0.3	6.5 ± 0.7	4327– 93	4453.1 ± 0.4	4.3 ± 0.5	4452– 0
4249.0 ± 0.3	10.1 ± 1.0	4249– 0	4544.1 ± 0.5	1.6 ± 0.4	
4253.7 ± 0.3	11.2 ± 1.1	4253– 0	4699.3 ± 0.7	0.5 ± 0.3	4793– 93

[a] The relative intensity can be converted to transitions per 100 β decays using the factor 0.0321, assuming a 5% β branch to the ground state of ^{91}Sr.
[b] Denotes transition identified only in coincidence.
[c] Individual intensities split as determined from coincidence data.

$\log ft$ values for the β branches, little can be stated on the spin-parity values for the other levels below 2 MeV, except to postulate that they are negative parity, and in a broad spin range. The level at 1615.2 keV, though heavily β fed, as in Ref. 1, is not found in this work to have an unambiguous allowed $\log ft$ value for its β branch.

Allowed transition $\log ft$ values appear with the 2593.2, 2844.7, 2861.5, 3002.3, 3090.7, and 3113.6 keV levels, and these levels, along with most of those above 3900 keV, have positive parity as indicated from β branching. The levels at 2593.2, 2844.7, 3002.3, and 3113.6 keV all deexcite to the ground state, and thus probably have spins restricted to $\frac{3}{2}$ or $\frac{5}{2}$. The origin of these positive-parity states is not easily derived, but they possibly involve at least some component of the type $\pi(p_{3/2})^{-1}\nu(p_{3/2})^{-1}(d_{5/2})^5$, reflecting the decay of a deep-lying neutron into a valence proton. Deexcitations to the ground state are easily accomplished from such a configuration by single-particle processes.

The lack of more definitive information about the excited levels below 1000 keV imposes severe limitations on being able to say more about this very complicated and interesting level scheme. Future experiments should include angular correlation or comprehensive conversion electron measurements to define the properties of the basic low-lying levels, so that the many higher levels can be more fully interpreted.

B. ^{91}Sr levels

The spin-parity for the ground state of ^{91}Sr of $\frac{5}{2}^+$ conforms with the systematics for $N=53$ isotones shown in Fig. 7. The first excited state has a postulated value of $\frac{3}{2}^+$, on the basis of the systematics and the established $E2$ character of the 93.6-keV transition. The $\frac{3}{2}^+$, seniority-3 state which is systematically present in these isotones is expected to deexcite to the $\frac{5}{2}^+$, seniority-1 ground state via an $E2$ transition.[44] Such a con-

TABLE V. Comparison of major γ-ray intensities with prior ^{91}Rb studies.

Energy (keV)	This work	Achterberg *et al.*	Mason and Johns
93.63	1000 ± 51	1000 ± 100	1000
345.43	246 ± 12	340 ± 4	316
602.85	84 ± 4	102 ± 15	105
1137.24	115 ± 6	148 ± 15	124
1849.27	98 ± 5	147 ± 15	100
1970.99	199 ± 10	310 ± 30	258
2564.19	372 ± 19	576 ± 60	526
3599.67	309 ± 16	360 ± 40	368
4078.24	121 ± 6	160 ± 2	150

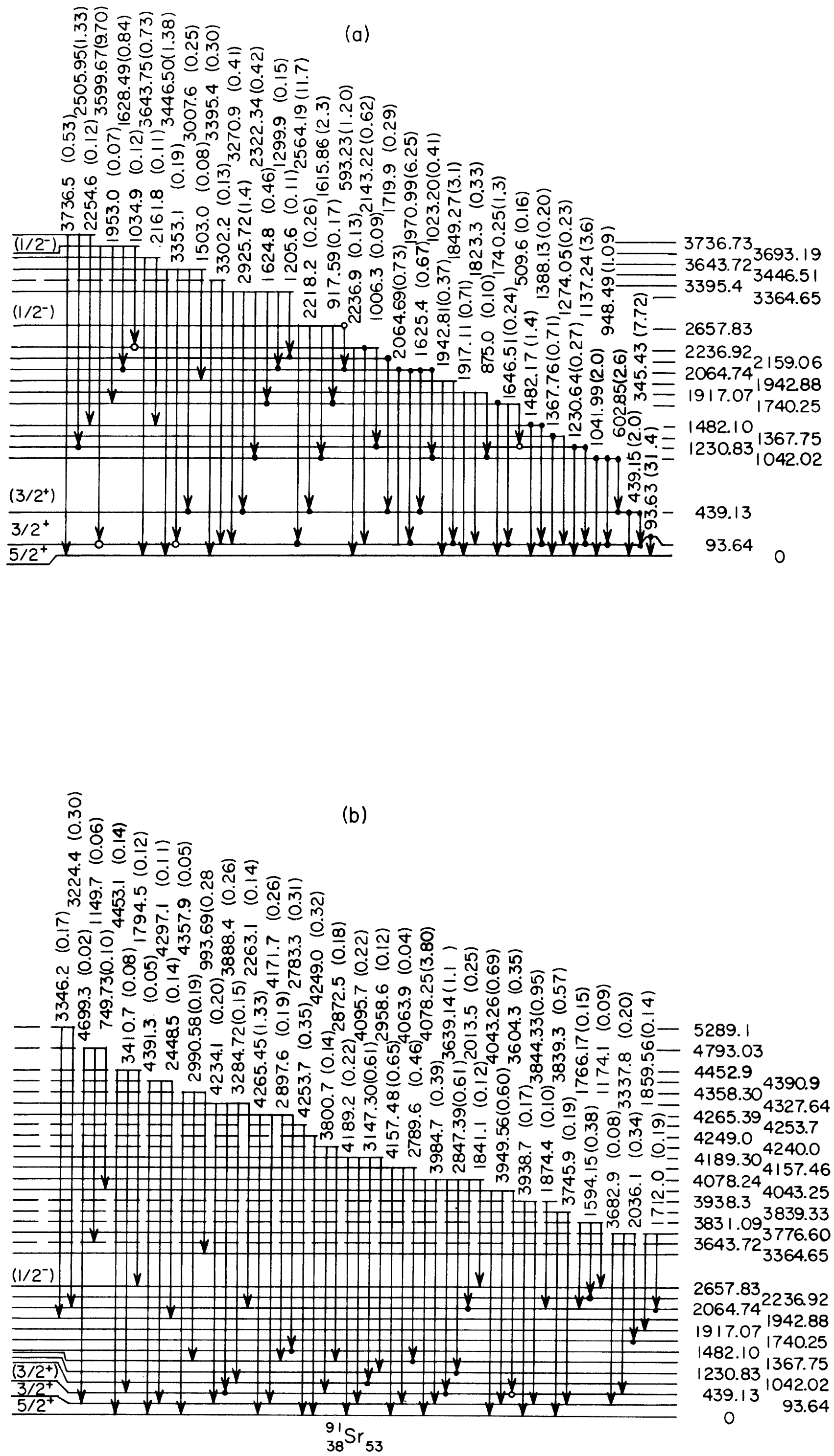

FIG. 4. Level scheme for ^{91}Sr populated in the decay of ^{91}Rb: (a) levels up to 3736 keV; (b) levels from 3776 to 5289 keV.

TABLE VI. Logft values and β branching for ^{91}Rb decay.

Level energy (keV)	Percent β branching	Logft
0.00 ± 0.00	5 ± 5	$7.45^{+0.00}_{-0.31}$ [a]
93.64 ± 0.04	23 ± 4	6.74 ± 0.08 [a]
439.13 ± 0.06	2.1 ± 0.5	7.66 ± 0.10 [a]
1042.02 ± 0.10	1.7 ± 0.3	7.51 ± 0.07 [a]
1230.83 ± 0.09	1.60 ± 0.25	7.46 0.07 [a]
1367.75 ± 0.07	<0.03	>9.08
1482.10 ± 0.14	1.01 ± 0.13	7.55 ± 0.06 [a]
1740.25 ± 0.09	0.67 ± 0.12	7.61 ± 0.08 [a]
1917.07 ± 0.12	1.00 ± 0.11	7.35 ± 0.05 [a]
1942.88 ± 0.10	3.1 ± 0.3	6.85 ± 0.04
2064.74 ± 0.22	4.7 ± 0.5	6.60 ± 0.05
2159.06 ± 0.23	0.18 ± 0.05	7.98 ± 0.12 [a]
2236.92 ± 0.11	0.33 ± 0.08	7.66 ± 0.11 [a]
2657.83 ± 0.20	15.3 ± 1.2	5.75 ± 0.04
3364.65 ± 0.20	2.68 ± 0.22	6.02 ± 0.04
3395.4 ± 0.4	0.43 ± 0.08	6.79 ± 0.08
3446.51 ± 0.18	1.91 ± 0.18	6.10 ± 0.04
3643.72 ± 0.20	0.78 ± 0.10	6.33 ± 0.06
3693.19 ± 0.14	10.7 ± 0.9	5.14 ± 0.04
3736.73 ± 0.14	1.98 ± 0.20	5.84 ± 0.05
3776.60 ± 0.19	0.95 ± 0.12	6.12 ± 0.06
3831.09 ± 0.25	0.63 ± 0.07	6.25 ± 0.05
3839.33 ± 0.24	0.76 ± 0.09	6.16 ± 0.06
3938.3 ± 0.5	1.22 ± 0.13	5.86 ± 0.05
4043.25 ± 0.14	1.52 ± 0.20	5.65 ± 0.06
4078.24 ± 0.10	6.3 ± 0.5	5.00 ± 0.04
4157.46 ± 0.18	1.15 ± 0.11	5.65 ± 0.05
4189.30 ± 0.16	1.17 ± 0.11	5.61 ± 0.05
4240.0 ± 0.4	0.32 ± 0.06	6.11 ± 0.09
4249.0 ± 0.3	0.32 ± 0.04	6.10 ± 0.06
4253.7 ± 0.3	0.35 ± 0.04	6.05 ± 0.06
4265.39 ± 0.15	2.10 ± 0.17	5.26 ± 0.04
4327.64 ± 0.24	0.76 ± 0.08	5.63 ± 0.05
4358.30 ± 0.21	0.52 ± 0.06	5.76 ± 0.06
4390.9 ± 0.3	0.29 ± 0.05	5.96 ± 0.08
4452.9 ± 0.3	0.33 ± 0.07	5.83 ± 0.10
4793.03 ± 0.25	0.18 ± 0.03	5.55 ± 0.09
5289.1 ± 0.3	0.47 ± 0.09	3.89 ± 0.11

[a] Logf_1t >8.5, so first forbidden unique β transition is not excluded.

figuration does not, however, explain the large β branch to this level, which suggests a small admixture of the $\nu(d_{5/2})^2(d_{3/2})$ configuration, but not enough to affect the $E2$ dominance of the 93.6-keV transition.

Mason and Johns[11] have performed a calculation according to the method of Talmi[44] and Vervier[45] for the ^{91}Sr seniority-3 states, using the 0^+, 2^+, and 4^+ states of ^{90}Sr. They predict that the $\frac{3}{2}^+$ seniority-3 level should lie at 25 keV, and the $\frac{9}{2}^+$ seniority-3 level should be near 1230 keV. The calculated $\frac{3}{2}^+$ state position is in reasonable agreement with experiment, and the $\frac{9}{2}^+$ state is not likely to be seen in this study owing to the relatively low spin of the parent state. A level at 1367.8 keV is noted with very little, if any, β branching, but this level also has a transition to the $\frac{3}{2}^+$ first excited state, so is not considered to be the $\frac{9}{2}^+$ state predicted using the above model.

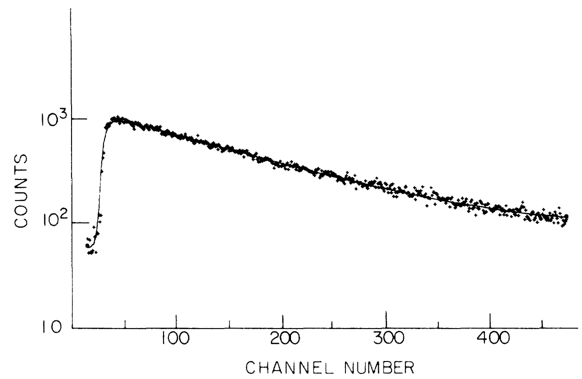

FIG. 5. Delayed coincidence time spectrum for the 93.6-keV transition in ^{91}Sr.

Using the conversion coefficients determined by Achterberg *et al.*,[1] the $M1/E2$ character of the transitions depopulating the 439.1-, 1042.0-, and 1230.8-keV levels restrict these levels to positive parity, and the 1042.0-keV level to spins $\frac{3}{2}$ or $\frac{5}{2}$. The large logft values of the β branches to the other levels below 2500 keV suggest that they are also of positive parity, but the possible spin values cannot be restricted to one or two values without more definitive information such as angular correlations.

Intense transitions to the 93.6-keV state and the absence of transitions to the ground state provide a weak argument for $\frac{1}{2}^-$ assignments to the 2657.8- and 3693.2-keV levels populated by allowed β decay. If the β decay proceeds via a $p_{1/2}$ neutron decaying to a $p_{3/2}$ proton, then these levels would have at least an admixture of the $\nu(d_{5/2})^4(p_{1/2})^{-1}$ configuration, and the deexcitation would be preferred to the $\frac{3}{2}^+$ first excited state. In contrast, the β branches to the 4078.2- and 4265.4-keV levels result in intense transitions to the ground state, and could indicate the decay of a $p_{3/2}$ neutron leaving at least an admixture of the $\nu(d_{5/2})^4(p_{3/2})^{-1}$ configuration, for which the deexcitation to the ground state involves a strong

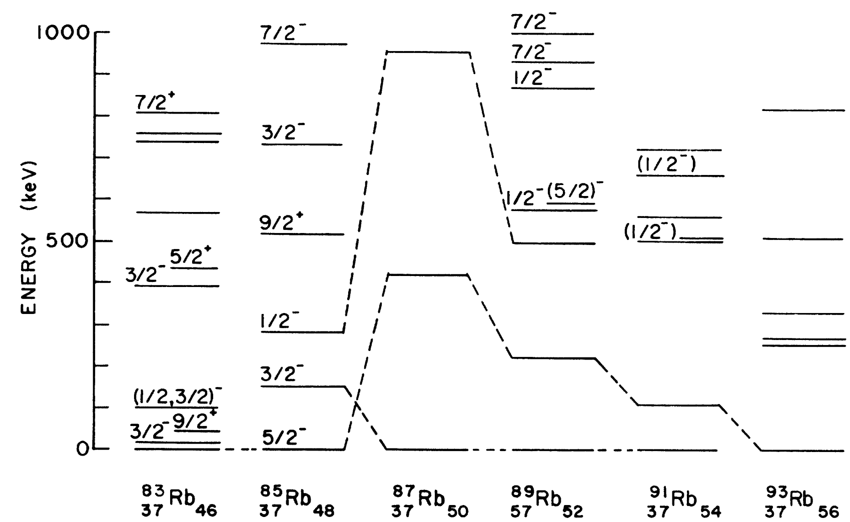

FIG. 6. Systematics of levels in odd-A Rb nuclei up to 1000 keV. Data taken from Refs. 33–37 for $A = 83$, 85, 87, 89, and 93, respectively.

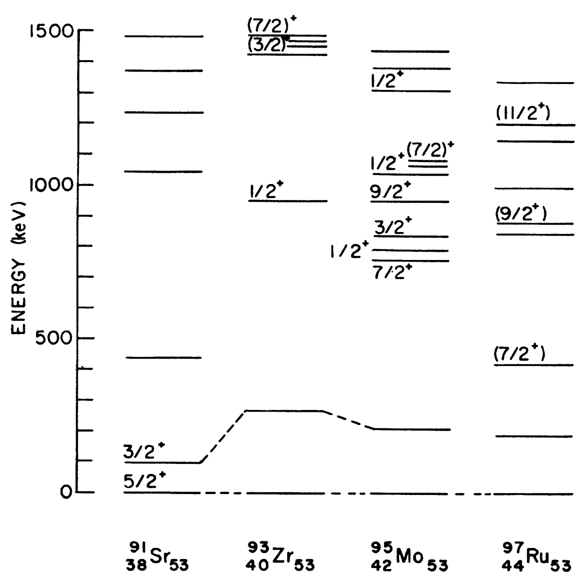

FIG. 7. Systematics of levels in $N = 53$ nuclei up to 1500 keV. Data taken from Refs. 41–43 for $A = 93$, 95, and 97, respectively.

single-particle component. Thus, the latter two levels could have spin-parity of $\frac{3}{2}^-$.

There are other possibilities for negative-parity levels between 3700 and 5300 keV, dictated by the low $\log ft$ values for the β branches seen. There seems to be no reasonable way to limit the choice of spins further than the $\frac{1}{2}$, $\frac{3}{2}$, and $\frac{5}{2}$ indicated from the allowed β decays without further information about the first few excited states.

The speculative nature of the structures suggested above for ^{91}Rb and ^{91}Sr should be stressed in view of the difficulty to confirm even the few assignments proposed. The need for further studies is obvious; other spectroscopic measurements, such as angular correlations and conversion coefficients, are difficult but should give additional information needed to develop further structure interpretation. Certainly, (d, p) reaction studies with targets of ^{90}Sr would be very valuable and should be possible using targets prepared by mass separation. Such studies would provide important new information on the single-particle nature of the neutron structures observed in ^{91}Sr.

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