Three-particle one-hole configurations in odd-odd ^{134}I and the decay of ^{134}Te†

R. A. Meyer and J. H. Landrum
Lawrence Livermore Laboratory, University of California, Livermore, California 94550

S. V. Jackson*
Lawrence Livermore Laboratory, University of California, Livermore, California 94550
and Chemistry Department, University of Maryland, College Park, Maryland 20742

W. H. Zoller‡ and W. B. Walters‡
Chemistry Department, University of Maryland, College Park, Maryland 20742

(Received 23 June 1975)

The levels of ^{134}I have been studied by singles and coincidence Ge(Li) spectrometers. To obtain 42-min ^{134}Te free from its daughter, 52.8-min ^{134}I, γ-γ coincidence data were taken with ^{134}Te adhered to an ion exchange column while its daughter was being continually eluted. Levels were identified at (J^π in parentheses) ground state (4^+), [44.4 (5^+)], 79.445 (3^+), 181.89 [3^+ (2^+)], 210.47 [2^+ (3^+)], 645.44 (2^+), 846.65 (1^+), 923.51 (1^+), and 1107.44 keV (1^+). The levels are discussed within the framework of three-proton-particle one-neutron-hole configurations.

[RADIOACTIVITY Measured E_γ, I_γ, γ-γ coincidence; deduced ^{134}I levels; activity isolated from fission, sources measured while daughter product continually eluted from ion-exchange column.]

INTRODUCTION

The influence of three-particle clustering has been used to account for several features of the odd-mass iodine nuclei.[1-5] Alaga and co-workers[3] have explained the systematic appearance of a second $\frac{5}{2}^+$ level by incorporating a $(1g_{7/2})^3$ three-proton configuration. They have also been able to account for the large magnitude of the $B(E2)$ transition probability between the $\frac{7}{2}{}_1^+$ and $\frac{5}{2}{}_1^+$ levels in nuclei such as ^{129}I (Ref. 4) and ^{131}I (Ref. 5). One might expect that the presence of such three-proton configurations would result in a more complex level structure in the odd-odd iodine ($Z = 53$) nuclei than in the odd-odd antimony ($Z = 51$) nuclei, such as ^{132}Sb which was recently studied by Kerek and co-workers.[6]

The decay of 42-min ^{134}Te was first studied in detail by Berg, Fransson, and Bemis.[7] Additional γ rays have been identified by Berg and Hoglund[8] as well as by Kerek *et al.*[9] However, all of these studies have had the disadvantage of the presence of the 52.8-min ^{134}I daughter, which grows in after separation of 42-min ^{134}Te from fission products. This problem was avoided in the present γ-γ coincidence studies by devising a method of continuous chemical separation, employing an ion exchange column under conditions such that tellurium adhered to the column while iodine did not. This method has allowed us to identify and place several previously unobserved transitions arising from the decay of ^{134}Te.

EXPERIMENTAL PROCEDURE

The ^{134}Te sources for γ-ray singles counting were prepared by isolating tellurium from mixed fission products produced by irradiating enriched ^{235}U with thermal neutrons at the Lawrence Livermore Laboratory (LLL) pool-type reactor. The iodine activities were removed from the fission product as PdI, followed by rapid isolation of the tellurium activities. The sources, which contained ^{129}Te^g, ^{131}Te^g, and ^{133}Te^{m+g} in addition to ^{134}Te, were then counted using several different large volume Ge(Li) detectors as well as a high-resolution Ge(Li) x-ray detector.

Initial γ-γ coincidence measurements were performed at LLL using a PDP-9/Disk megachannel γ-γ coincidence spectrometer.[10] Sources of tellurium were isolated from ^{235}U fission products using the LLL automated fast chemistry facility (described in detail in Ref. 1). Even though fresh sources could be produced every 20–25 minutes, the data contained a large number of unwanted coincidence events resulting from the presence of large amounts of iodine daughter activities. This interfered with an unambiguous determination of coincidence relationships. To alleviate this problem, a method was advised in which the iodine daughter activities were continuously removed from the tellurium activities (see Fig. 1), and a second γ-γ coincidence experiment was then performed.

The sources for the second coincidence experi-

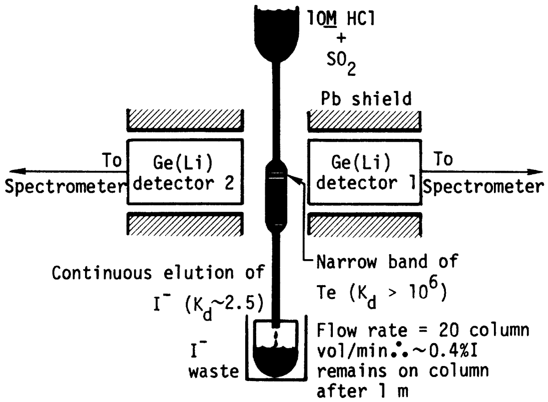

FIG. 1. Schematic plan of the γ-γ coincidence study in which the ^{134}I daughter activity was continuously eluted away from the ^{134}Te parent activity. (*Nota bene:* because Te^{IV} has a $K_d > 10^6$ it remains in a narrow well-defined band located at approximately the logitudinal axis of the coaxial detectors while the I^-, which has a K_d of ~2.5, is immediately removed from its site of production at the Te band. Thus, the elutant flow rate governs the amount of ^{134}I in front of the Ge(Li) diodes at any one time.)

ment were prepared by separating tellurium from the fission products of enriched ^{235}U irradiated with thermal neutrons at the National Bureau of Standards (NBS) reactor. First, the radiochemically pure tellurium was absorbed onto an ion-exchange column (30 mm long × 7 mm i.d.) of AG 1 × 8, 100 to 200 mesh resin. The I^- was then continuously eluted with 10 M HCl[11] containing enough SO_2 to insure that all iodine was reduced to I^-. Under these conditions the Te^{IV} has a distribution coefficient (K_d) greater than 10^6 while I^- has a K_d of approximately 2.5. The free column volume was 0.5 cm^3 and the flow rate was maintained at 10 cm^3/min; thus, 20 column volumes passed through each minute. A calculation, using the above parameters, shows that at the end of the first minute no more than 0.4% of the initial iodine activity remained on the column. Each minute thereafter, all but 0.4% of the iodine that had grown in was removed. Since the growth amounts to about 2% in 1 min, a constant contamination level of ≤ 0.01% was quickly achieved. The bottom of the column was fitted with a long, thin tube (1-mm i.d.) so that the eluted activities were removed very quick-

TABLE I. Energy and intensity of γ-rays in the decay of ^{134}Te.

$E\gamma(\Delta E\gamma)$ (keV)	$I\gamma(\Delta I\gamma)$ Singles	Coincidence	(gate/fiducial)	Assignment From	To
29.574 [a]	···	< 0.1	(180/435)	210	181
76.827(62)	0.93(8)	0.7(3)	(767/259)	923	846
79.445(12)	70(1)	F [b]	···	79	g.s.
101.420(30)	1.1(2)	1.0(3)	(742/180)	181	79
131.050(200)	0.6(2)	1.0(3)	(435/210)	210	79
137.000(400)	···	0.3(2)	(742/180)	180	44
180.891(15)	60(2)	F	···	180	g.s.
183.050(125)	2(1)	A [c]	···	1106	923
201.235(15)	29(1)	30(2)	(435/277)	846	945
210.465(16)	73(1)	F	···	210	g.s.
259.800(300)	1.6(3)	A	···	1106	846
277.951(8)	71(2)	F	···	923	645
435.063(42)	62(3)	64(5)	(277/565)	645	210
460.997(22)	36(1)	35(1)	(435/277)	1106	645
464.640(49)	17.0(4)	15(3)	(277/565)	645	181
565.992(13)	63(2)	60(3)	(79/767)	645	79
636.258(95)	···	5.7(7)	(210/435)	845	210
645.400(100)	···	3.0(3)	(277/565)	645	g.s.
665.850(100)	···	4.0(6)	(180/464)	846	181
712.971(48)	14(1)	16(3)	(210/435)	923	210
742.586(18)	49(2)	52(3)	(180/464)	923	79
767.196(21)	100(2)	F	···	846	79
844.055(46)	4(1)	8(3)	(79/767)	923	79
896.020(100)	···	1.5(4)	(210/435)	1106	210
925.546(68)	5.5(6)	6.1(6)	(180/464)	1106	181
1027.000(100)	1.5(4)	1.3(4)	(79/767)	1106	79

[a] Energy deduced from decay scheme.
[b] Fiducial γ ray, with singles intensity adopted as the intensity standard for a gated spectrum.
[c] Observed in coincidence spectra, however, no fiducial γ ray could be assigned.

ly from the vicinity of the detectors. In a tube this size the eluted activities moved downward at a rate of 5 to 6 cm/sec. During the elution, the tellurium remained in a narrow band at the top of the resin, midway between the detectors. A fresh tellurium source was added each hour to maintain a fairly constant counting rate. After each new addition of tellurium the column was flushed for 2 min before counting was resumed. This procedure was continued until approximately 6 million coincidence events were accumulated on magnetic tape. The γ-γ coincidence spectrometer is described in detail in Ref. 12.

In all experiments the tellurium sources contained substantial amounts of $^{129}Te^{g}$, $^{131}Te^{g}$, and $^{133}Te^{m+g}$ contaminating activities. The γ rays from these activities were identified on the basis of earlier studies[1,4,5] of the decay of these nuclides, in which these activities were produced free of ^{134}Te. The ^{134}Te γ rays were identified on the basis of half-lives and detailed coincidence relationships.

RESULTS AND DECAY SCHEME

The γ-ray energies and relative intensities for the decay of ^{134}Te to levels of ^{134}I are given in Table I, and the results of the γ-γ coincidence studies are given in Table II. Several transitions were observed solely in gated coincidence spectra, and their relative intensities were determined in those coincidence spectra on the basis of fiducial γ rays as indicated in Table I. The determination of many relative intensities from both singles and coincidence measurements provided a sensitive test of the consistency of our proposed ^{134}Te decay scheme. In Fig. 2 we present a portion of the spectrum in coincidence with the 742-keV γ ray, showing evidence for the 137-keV transition. In Fig. 3 we show a portion of the coincidence spectrum resulting from gating with the 210-keV γ ray.

Our proposed decay scheme for 42-min ^{134}Te is shown in Fig. 4. Coincidence gates were set which included all transitions except those depicted with a half circle at their upper end. Transitions which appeared in one or more gated coincidence spectra are depicted with full circles at their lower end. For completeness, we have included the 3.7-min isomeric level at 316.3 keV in ^{134}I which was observed by Coryell *et al.*[13] This isomer decays via an $E3$ transition[13-15] to the level at 44 keV and has been suggested to have $J^{\pi} = 8^{-}$.

The three levels at 846, 923, and 1107 keV are each fed by a β group having a $\log ft$ value[16] of ap-

TABLE II. γ-γ coincidences in the decay of ^{134}Te.

Gate region (keV)	Principal photopeaks in gate (keV)	Coincident γ rays observed (keV)
76.6–82.2	79.445	76, 101, 131, 201, (259?), 277, 435, 461, 565, 742, 767, 844, 1027
177.8–185.8	180.891 183.0	(76?), (79?), (181?), 201, 210, 277, 435, 461, 464, 565, 665, (712?), 742, 844, 925
198.2–204.2	201.24	76, 79, 181, 210, 259, 435, 464, 565
207.5–213.5	210.465	183, 201, 277, 435, 461, 636, 712, 896
257.0–263.0	259	79, 201, (435?), (565?), 767
255.3–280.6	277.95	79, 180, 183, 210, 435, 464, 565, 645
431.9–438.3	435.06	76, 131, 201, 259, 277, 461
457.7–464.3	461.00	79, 180, 210, 435, 464, 565, 645
461.8–467.4	464.64	101, 180, (183?), 201, (259?), 277, 461
563.0–569.0	565.99	(76?), 79, 201, 259, 277, 461
710.3–715.7	712.97	210
740.1–745.0	742.59	101, (137?), 180, 183
746.2–770.2	767.20	76, 79, 259
842.7–850.0	844.06	79, 183
1025.5–1032.0	1027.0	79

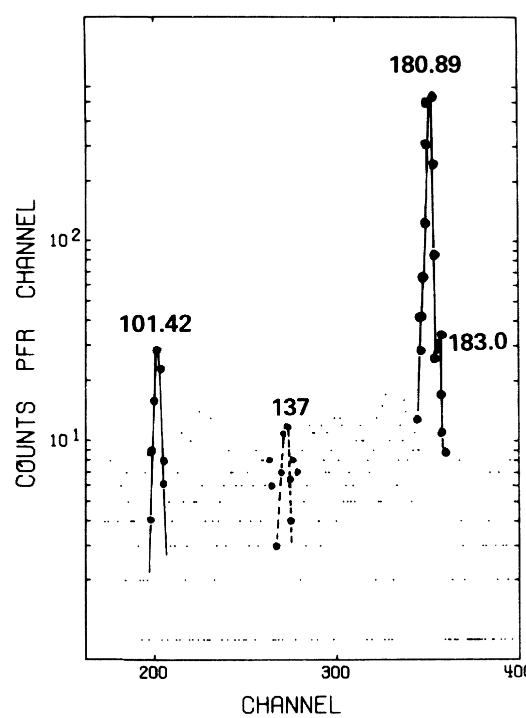

FIG. 2. A portion of the coincidence spectrum gated with the 742-keV γ ray.

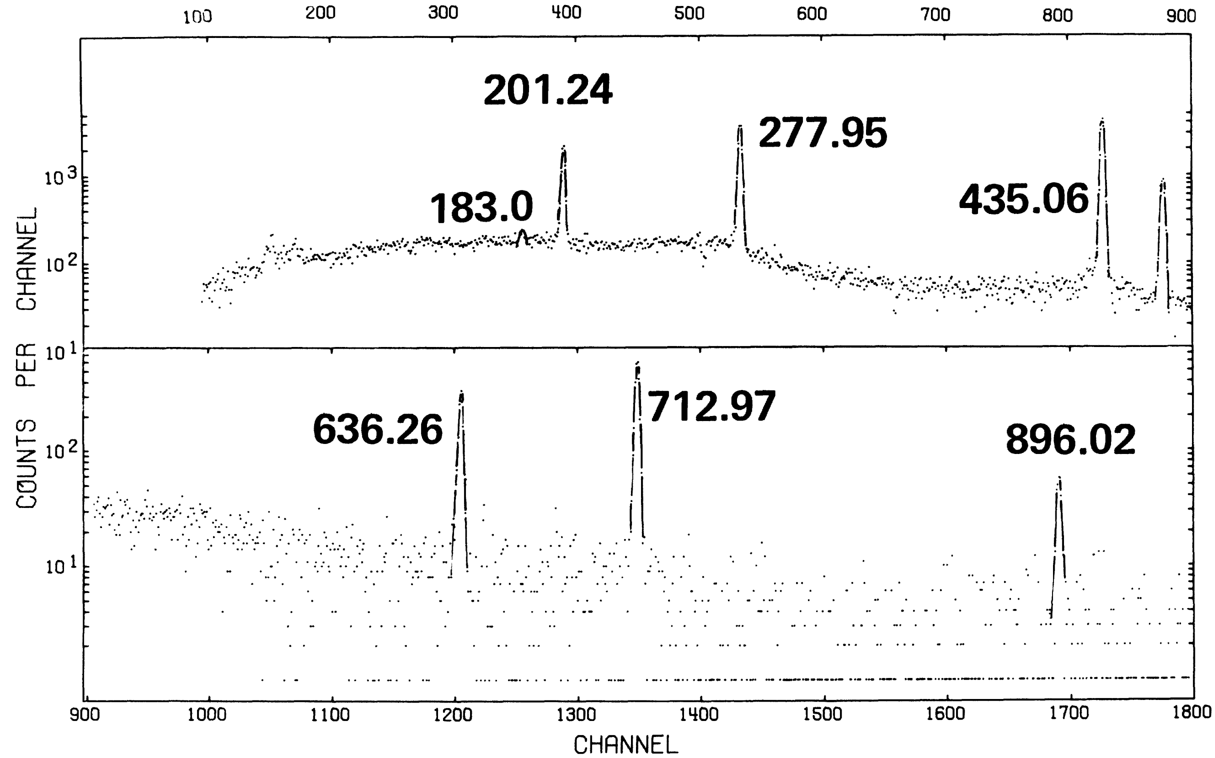

FIG. 3. A portion of the coincidence spectrum gated with the 210-keV γ ray.

proximately 4.7, which restricts their respective J^{π} values to 1^+. The β decay of the ground state of ^{134}I populates a level in ^{134}Xe at 2867 keV with a logft value of 5.9, indicating an allowed transition.[15] Conversion electron data[14] indicate this

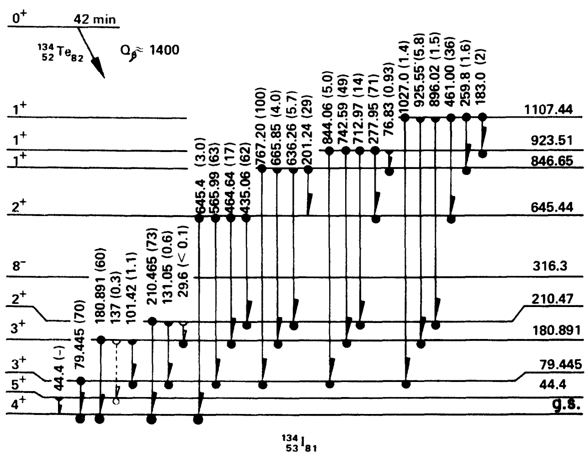

FIG. 4. The decay scheme of ^{134}Te. Coincidence gates were set on transitions indicated by a full circle at their upper end, and transitions appearing in one or more of the gated spectra are indicated by full circles at their lower end.

^{134}Xe level has $J^{\pi}=4^+$ or 5^+, thus limiting the ^{134}I ground state to $J^{\pi}=3^+$, 4^+, 5^+, or 6^+. The lack of an observed β branch[15] to either of the first two 2^+ excited states in ^{134}Xe makes a 3^+ assignment very unlikely. The 79-keV level is fed by γ transitions from all three 1^+ levels and deexcites to the ground state via a transition with partial $M1$ multipolarity.[7,8,15] This limits the ground state to $J^{\pi}=4^+$ and the 79-keV level to $J^{\pi}=3^+$. These assignments are consistent with the lack of any observed ground state transitions from the levels at 846, 923, and 1107 keV.

The isomeric state at 316 keV deexcites via a 271.9-keV $E3$ transition[13-15] to the level at 44 keV. The $E3$ nature of this transition, its strong coincidence with K x rays,[13-14] and the total yield[13] of iodine K x rays in the decay of ^{134}I^m all combine to indicate the 44.4-keV transition is at least partially $M1$ in character. This $M1$ character is further supported by the total conversion coefficient of the 44.4-keV transition of $\alpha_T = 9.5 \pm 1.3$ (determined by an intensity balance of the 44-keV level based on γ-ray[13] and conversion electron[14] measurements of ^{134}I^m decay) in conjunction with the measured half-life of the 44.4-keV level of <10 nsec.[13] The lack of an observed crossover transition from the isomer to the ground state ($I_\gamma < 0.6\%$

of the 271.9-keV γ-ray intensity[13] and no conversion electron lines[14]) favors the assignment of $J^\pi = 5^+$ to the 44-keV level and $J^\pi = 8^-$ to the 3.7-min isomeric level.

The three levels at 180, 210, and 645 keV are all populated by transitions from the 1^+ levels, and all feed the 3^+ level at 79 keV as well as the 4^+ ground state. Thus, their J^π assignment is limited to 2^+ or 3^+. We have tentative evidence for a 137-keV γ ray, which could be the transition from the 180-keV level to the 44-keV 5^+ level. If this γ ray is present it would restrict the 180-keV level to a spin and parity of 3^+. This assignment is further supported by the probable dipole character[7,9,15] of the 180-keV transition to the 4^+ ground state. The low intensity of the transition to the 4^+ ground state from the 645-keV level suggests a 2^+ assignment for this level. The lack of an observed transition from the 645-keV level to the 44-keV 5^+ level ($I_\gamma < 0.1$) supports this assignment. Similarly, the lack of an observed transition from the 210-keV level to the 44-keV 5^+ level ($I_\gamma < 0.05$) suggests a 2^+ assignment for this level.

DISCUSSION

In Fig. 5 we show the levels of ^{134}I and of nearby odd-odd nuclei.[17-22] It may be noted that ^{134}I has a higher level density than ^{132}Sb, and particularly that ^{134}I has three 1^+ states lying below 1500 keV, whereas ^{132}Sb has only one such state. It is possible to account for this difference in terms of a simple model involving coupling of the low-lying states in the neighboring odd-Z and odd-N nuclei. In Fig. 6 we present the levels of odd-proton ^{133}I (Ref. 1) and of odd-neutron ^{133}Te (Ref. 1) along with possible multiplets that may be constructed by a zeroth-order coupling of the several low-lying states. The observed difference in level density between ^{134}I and ^{132}Sb can be attributed to the presence in ^{133}I of extra $\frac{5}{2}^+$ and $\frac{3}{2}^+$ states below 1 MeV which are not present in ^{131}Sb. (*Nota bene*: The only excited state below 1 MeV in ^{131}Sb is a $d_{5/2}$ state at 798 keV.[21,22])

It is instructive to compare the properties of the levels with $J^\pi = 1^+$ in the four nuclei shown in Fig. 5. In ^{134}I we observe nearly identical logft values for the β groups feeding the 1^+ states, and we observe γ-ray decay patterns marked by strong branching to the 2^+ level at 645 keV. For each 1^+ state, the transition to the 2^+ level at 645 keV ($\pi_1\nu_1$ or $\pi_1\nu_0$ in character) has a reduced transition probability of approximately 60 times that of the transition to the 2^+ $\pi_0\nu_0$ level at 210 keV. A similar γ-ray branching is observed in the decay of the 1^+ states in ^{130}Sb and ^{132}Sb. In ^{132}I the only 2^+ level available for the 1^+ level at 278 keV to decay to is the 2^+ member of the $\pi_0\nu_0$ multiplet, and a 1.42-nsec lifetime is observed for the 278 keV 1^+ state. For ^{134}I the lowest predicted 1^+ state has a $\pi_1\nu_0$ configuration and forms part of a zeroth-order multiplet at approximately 310 keV as shown in Fig. 6. In ^{132}Sb, Kerek *et al.*[6] showed that the inclusion of a δ force resulted in the $\pi_1\nu_0$ 1^+ state being pushed up by approximately 600 keV. A similar sizeable elevation is seen in ^{134}I for the $\pi_1\nu_0$ 1^+ state. In spite of much higher β-decay energies [2.0 MeV for ^{130}Sn (Ref. 23) and 3.0 MeV for ^{132}Sn (Ref. 6)], only two 1^+ states in ^{130}Sb and only one 1^+ state in ^{132}Sb have been observed. In ^{130}Sb the 1^+ state at 1042 keV is populated by a much stronger β branch (logft = 3.9) than is the 1^+ state at 697 keV (logft = 5.1). The single 1^+ state in ^{132}Sb is populated with a logft value of 4.0. The total β transition strength in the decay of ^{134}Te is approximately

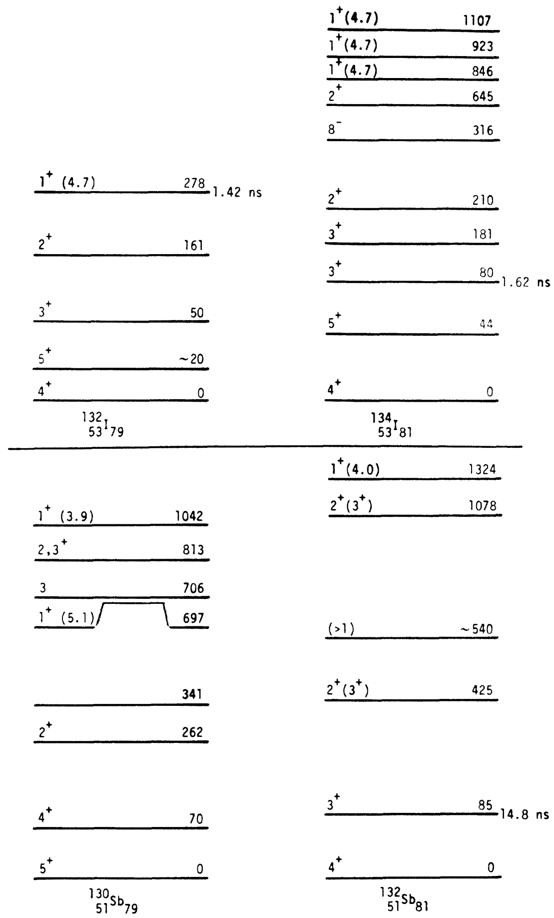

FIG. 5. Experimentally observed levels of $_{51}$Sb and $_{53}$I nuclei for $N = 79$ and 81 (this work and Refs. 17–22). (*Nota bene:* The energy scale is approximately logarithmic.) Experimentally determined half-lives are indicated to the right of the appropriate level. For each 1^+ level, the logft for the population of that level from the 0^+ even-even precursor is shown in parentheses to the right of the $J^\pi = 1^+$ value.

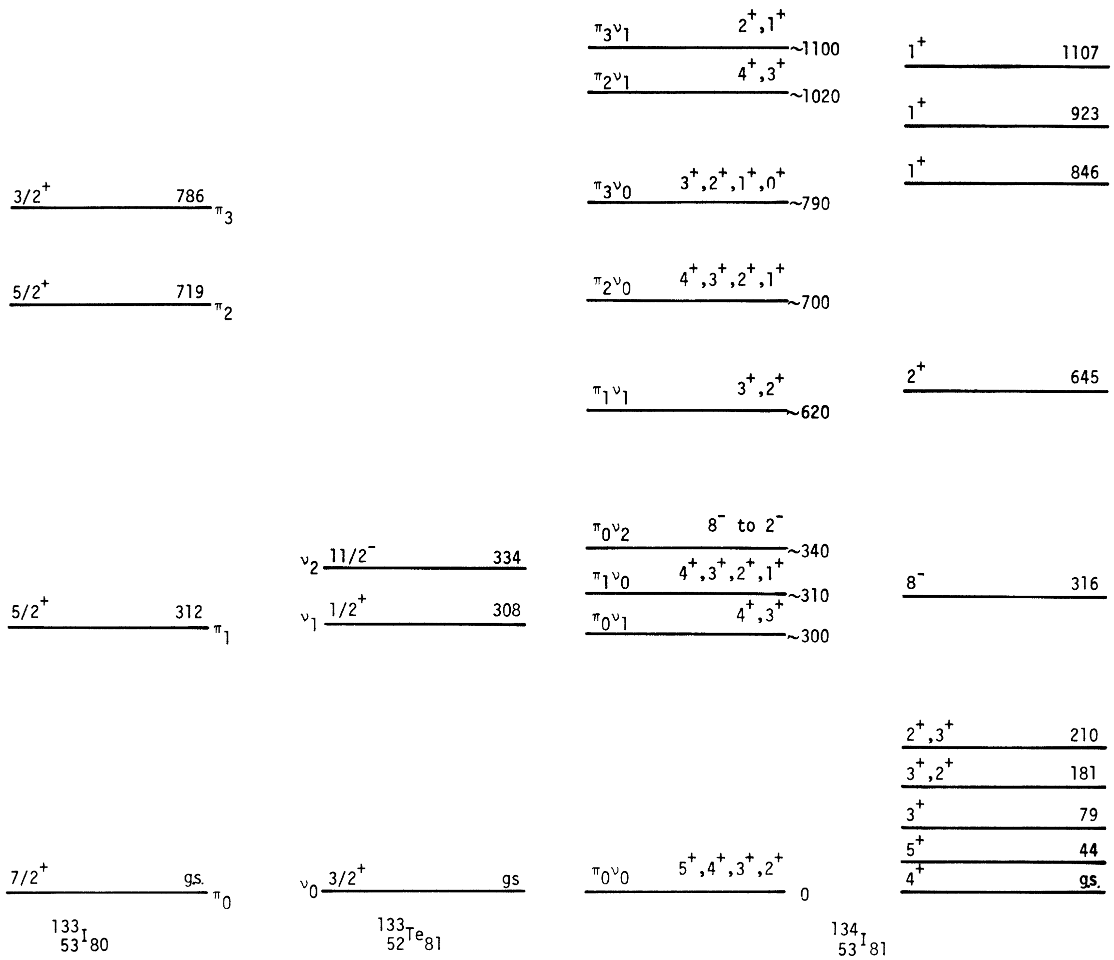

FIG. 6. The known levels of ^{133}I ($Z=53$) and of ^{133}Te ($N=81$) (both from Ref. 1) and the zeroth-order multiplets expected from coupling these levels in ^{134}I ($Z=53$, $N=81$). The right-hand column shows the experimentally determined levels of ^{134}I.

equal to that in ^{130}Sn or ^{132}Sn decay; however, in the ^{134}Te case the β strength is spread nearly equally over three 1^+ states.

An indication of the strong mixing of configurations in ^{134}I can be obtained by comparing the relative β-decay rates to the 1^+ states in ^{130}Sb, ^{132}Sb, and ^{134}I. The β-decay process involves the conversion of a core neutron into a $g_{7/2}$ or $d_{5/2}$ proton. In the cases under discussion, the only channel available to the β decay is $\nu d_{3/2}$ to $\Pi d_{5/2}$, leaving the daughter nucleus with an odd $d_{3/2}$ neutron. Thus, β decay should be strong only to the 1^+ states with a sizeable $(\Pi d_{5/2}\ \nu d_{3/2})$ component in their configuration. In ^{132}Sb, this is the only state available at low energy and a $\log ft$ value of 4.0 is observed. The expected configurations in ^{130}Sb for the two 1^+ states would be $(\Pi d_{5/2} \nu d_{3/2})\ 1^+$ and $(\Pi d_{3/2} \nu s_{1/2})\ 1^+$, with the former expected at approximately 700 keV and the latter at approximately 1100 keV according to zeroth-order calculations. The strong β decay branch to the higher energy 1^+ level of the two levels in ^{130}Sb suggests that this state is predominantly $(\Pi d_{5/2} \nu d_{3/2})\ 1^+$ in character. The lower energy 1^+ level in ^{130}Sb most likely has a $(\Pi d_{3/2} \nu s_{1/2})\ 1^+$ configuration, the β transition to this level being slowed by the $\Delta l = 2$ forbiddenness. In ^{134}I the 1^+ levels are populated with nearly equal $\log ft$ values. In this case, mixing of the configurations is sufficient that clear-cut identifications are not possible on the basis of relative β-decay strength. The greater configuration mixing in ^{134}I is also evident in the lowest 3^+ to 4^+ transition. The 79-keV transition in ^{134}I has a 1.62-nsec lifetime, ten times faster than the equivalent 85-keV transition in ^{132}Sb.

A detailed interpretation of the level structure of odd-odd ^{134}I is greatly complicated by the high level density and the large configuration mixing.

Extrapolation from the one-proton-particle, one-neutron-hole (1Πp-1νh) nucleus ^{132}Sb, which has been shown to be understandable, to the 3πp-1νh nucleus ^{134}I is difficult, as is extrapolation to 1πp-3νh ^{130}Sb. Similarities can be noted, but these are by no means as systematic as are found for even-even and odd-mass nuclei.[1] On a zeroth-order basis it appears that the presence of low-lying three-proton states with $J^{\pi} = \frac{5}{2}^{+}$ and $\frac{3}{2}^{+}$ in the odd-A iodine nuclei might explain some of the properties of ^{134}I. Theoretical calculations incorporating three-particle effects, such as those performed by Alaga, Paar, and Sips,[3] would be useful in trying to understand the structure of the ^{134}I states.

ACKNOWLEDGMENTS

We wish to thank Dr. J. T. Larsen of LLL for the use of his γ-γ coincidence data reduction codes, the crews operating the Livermore pool-type and NBS reactors, and Ms. R. N. P. Anderson and Mr. L. Maynard for assisting in the data reduction and operation of the γ-ray spectroscopy equipment.

---

†This work was performed under the auspices of the U. S. Energy Research and Development Administration under Contract No. W-7405-Eng-48 and supported in part by the Defense Advance Research Projects Agency.

*Associated Western Universities Fellow to Lawrence Livermore Laboratory from the University of Maryland. Present address: Group P-2, Los Alamos Scientific Laboratory, Los Alamos, New Mexico 87544.

‡Consultant to Lawrence Livermore Laboratory. Permanent address: Chemistry Department, University of Maryland.

[1] R. A. Meyer, in Proceedings of the International Conference on Gamma-Ray Transition Probabilities, Delhi, India, 1974 (unpublished); Report No. UCRL-76207, 1975 (unpublished).

[2] R. A. Meyer, in *Problems of Vibrational Nuclei*, edited by G. Alaga (North-Holland, Amsterdam, 1975), Chap. 7.

[3] G. Alaga, V. Paar, and L. Sips, in Proceedings of the International Conference on Vibrational Nuclei, Zagreb, Yugoslavia, 1974 (unpublished).

[4] L. G. Mann, W. B. Walters, and R. A. Meyer (unpublished).

[5] S. V. Jackson, W. B. Walters, and R. A. Meyer, Phys. Rev. C 11, 1323 (1975).

[6] A. Kerek, G. B. Holm, P. Carle, and J. McDonald, Nucl. Phys. A195, 159 (1972).

[7] V. Berg, K. Fransson, and C. E. Bemis, Ark. Fys. 37, 203 (1968).

[8] V. Berg and A. Hoglund, Nucl. Phys. A175, 495 (1971).

[9] A. Kerek, G. B. Holm, S. Borg, and L.-E. deGeer, Nucl. Phys. A195, 177 (1972).

[10] L. G. Mann and J. B. Niday, in *Proceedings of the International Conference on Radioactivity and Nuclear Physics* (Gordon and Breach, New York, 1972), p. 313.

[11] Because of the corrosive nature of the elutant, the entire experimental setup was placed in a fume hood and all parts enclosed separately in polyethylene.

[12] K. E. Apt, Ph.D. thesis, Massachusetts Institute of Technology, 1971 (unpublished).

[13] C. D. Coryell, H. N. Erten, P. K. Hopke, W. B. Walters, R. Dams, and H. C. Griffin, Nucl. Phys. A179, 689 (1972).

[14] E. Achterberg, E. V. deAisenberg, F. C. Iglesias, A. E. Jech, J. A. Moragues, D. Otero, M. L. Pérez, A. N. Proto, J. J. Rossi, W. Schever, and J. F. Súarez, Phys. Rev. C 4, 188 (1971).

[15] E. A. Henry, Nucl. Data Sheets 15, 203 (1974).

[16] We use the estimated Q value of 1400 ± 1000 keV given by Henry (Ref. 15) and assume no direct β population of the ^{134}I ground state. We note that Henry (Ref. 15) points out that Q_{β} could conceivably be large enough to raise the logft value to the first forbidden limit. However, the Q_{β} estimate is from a reliable fitting procedure, and our failure to observe levels above 1107 keV suggests that the Q_{β} value is not as large as 2.4 MeV (see discussion in Ref. 15).

[17] A. Kerek, P. Carle, and S. Borg, Nucl. Phys. A224, 367 (1974).

[18] H. R. Hiddleston and C. P. Browne, Nucl. Data Sheets 13, 133 (1974).

[19] M. Diksić, L. Yaffe, and D. G. Sarantites, Phys. Rev. C 10, 1178 (1974).

[20] G. B. Holm, S. Borg, and B. Rydberg, Report No. CERN 70-30, 1970 (unpublished), p. 1006.

[21] G. B. Holm, G. I. Anderson, S. Borg, and L.-E. deGeer, Report No. CERN 70-30, 1970 (unpublished), p. 1008.

[22] I. Andersson, S. Borg, L.-E. deGeer, and G. Holm, in Annual Report, Research Institute for Physics, Stockholm, 1970 (unpublished), p. 131.

[23] H. R. Hiddleston and C. P. Browne, Nucl. Data Sheets 13, 133 (1974).