Decay of mass-separated ^{78}Zn

F. K. Wohn, John C. Hill, and D. A. Lewis

Ames Laboratory–U. S. Department of Energy and Department of Physics, Iowa State University, Ames, Iowa 50011

(Received 17 June 1980)

The decay of neutron-rich ^{78}Zn produced by the thermal neutron fission of ^{235}U was studied with mass-separated sources. The decay scheme was deduced from γ singles and coincidence measurements. The ^{78}Zn half-life was determined to be 1.47 ± 0.15 s and 57 γ transitions were placed in a level scheme for ^{78}Ga involving 19 excited states. The systematics of odd-odd Ga nuclides is discussed.

[RADIOACTIVITY ^{78}Zn [from ^{235}U(n,f)]: measured $T_{1/2}$, E_γ, I_γ, $\gamma\gamma$ coin., Ge(Li) detectors; ^{78}Ga deduced levels, J, π, logft. Mass-separated ^{78}Zn activity.]

I. INTRODUCTION

The development of an in-beam integrated-target ion source for use with the TRISTAN on-line mass-separator system has made possible the study of the decays of very short-lived neutron-rich Zn and Ga nuclei. In this work we report the first detailed study of levels in odd-odd ^{78}Ga populated in the decay of ^{78}Zn. This is part of a program to study the decays of neutron-rich Zn and Ga fission products in the vicinity of $N=50$. Preliminary results of this study have been presented earlier.[1]

The only previous information on the decay of ^{78}Zn was obtained by Matsushigue and Matsushigue and appears in published form only as a private communication to Aleklett *et al.*[2] A half-life of 1.6 s was given along with a rudimentary decay scheme, but detailed information on γ energies and intensities was not presented. The level scheme was used in interpreting γ-gated β spectra and deducing a Q_β value for ^{78}Zn of 6.01 ± 0.18 MeV. No information is available on levels in ^{78}Ga from reaction studies.

II. EXPERIMENTAL METHODS AND RESULTS

The sources of mass-separated ^{78}Zn were produced with the TRISTAN II on-line mass-separator system located at the Ames Laboratory Research Reactor. The separator system was essentially the same as that described earlier,[3] with the exception of the new ion source which is described in Ref. 4. The target, 2 g of ^{235}UO$_2$, was internal to the ion source in a neutron beam of 2×10^9 cm^{-2} s^{-1} thermal flux. This integrated-target ion source enabled us to separate more than a dozen nongaseous fission products.

Both low energy photon spectrometer (LEPS) and large volume Ge(Li) detectors were used in γ measurements. Single measurements were made to determine γ energies and intensities. The half-life was determined with γ spectrum multiscaling. Finally, γ-γ coincidence measurements were made to determine transition placements. All measurements were made on a moving tape collector.[3]

For spectrum multiscaling measurements 16 time bins, each of 0.8 s duration, were used. Counting started after the end of a 10-s collection

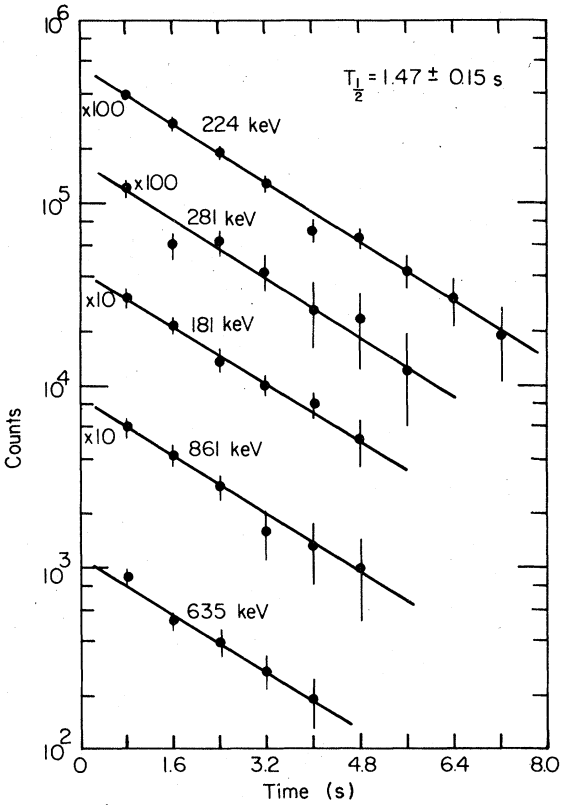

FIG. 1. Decay curves for γ rays emitted in the decay of ^{78}Zn. The half-life shown for each curve is 1.47 ± 0.15 s, the weighted average of independent fits.

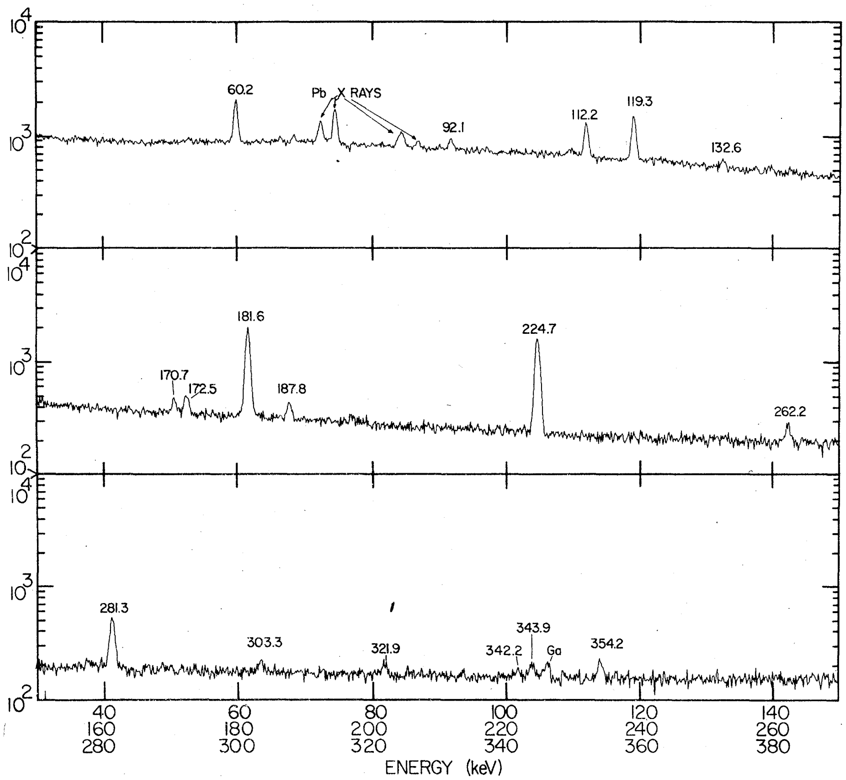

FIG. 2. Low-energy γ-ray spectrum obtained with LEPS detector of resolution 0.55 keV at 122 keV. ^{78}Zn peaks are labeled by energy.

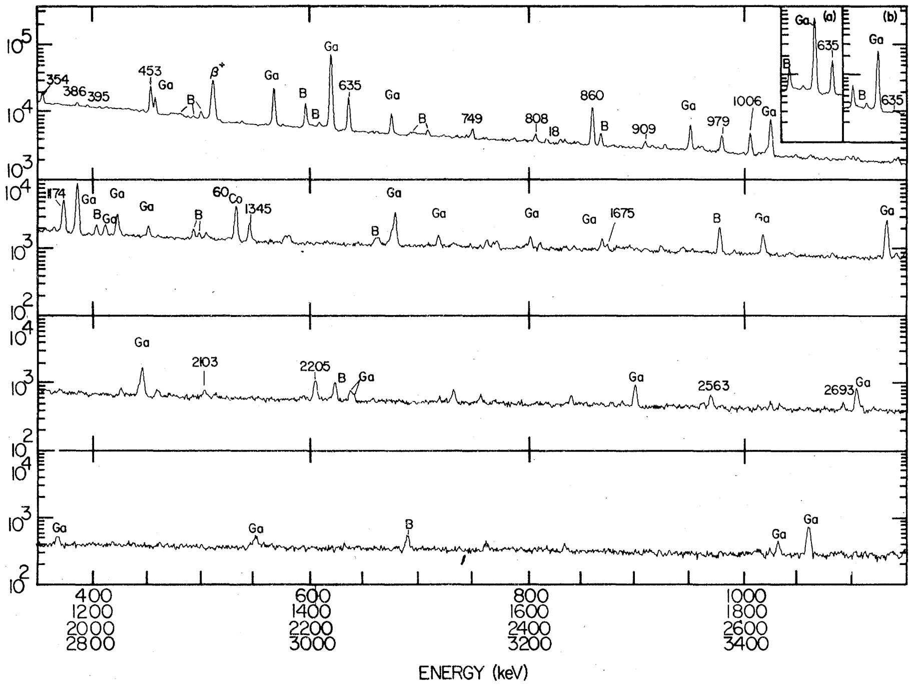

FIG. 3. Ge(Li) γ-ray spectrum with resolution 2.2 keV at 1.33 MeV. Selected Zn, Ga, and strong background (*B*) peaks are labeled. Inserts (a) and (b) indicate relative enhancements obtained between ^{78}Zn (635 keV) and ^{78}Ga (619 keV).

period. After the end of the cycle a new source was collected and the procedure repeated over a run period of 7.5 h. Decay curves for the 181-, 224-, 281-, 635-, and 861-keV γ rays are shown in Fig. 1. The fit lines shown for each decay curve indicate the weighted average half-life of 1.47 ± 0.15 s, which is in fair agreement with the value of 1.6 s quoted in Ref. 2.

Since both ^{78}Zn and ^{78}Ga activities were present in our samples, two different γ singles measurements were made, each measurement lasting about 7 h. A near equilibrium measurement was made by simultaneously collecting the activity and counting for 60 s, then moving the tape and repeating the procedure. In the second measurement, ^{78}Ga ($T_{1/2}$ = 5.5 s) was enhanced by collecting activity for 10 s, delaying for 5 s to allow ^{78}Zn to die away, and then moving the tape to a shielded position for a 10-s counting period.

A representative LEPS γ spectrum [with full width at half maximum (FWHM) of 0.55 keV at 122 keV] is shown in Fig. 2, and a Ge(Li) spectrum (with FWHM of 2.2 keV at 1.33 MeV) is shown in Fig. 3. No γ rays above 3.6 MeV have been assigned to the ^{78}Zn decay. The insert in Fig. 3 shows the spectrum in the neighborhood of the 619-keV γ ray from ^{78}Ga and the 635-keV γ ray from ^{78}Zn. The relative intensities of these two γ rays indicate the relative enhancement of the ^{78}Zn and ^{78}Ga activities in the two γ singles measurements.

Standard sources of ^{56}Co, ^{182}Ta, and ^{226}Ra were used to calibrate γ energies and intensities and to map the nonlinearities of the detector systems. The energies, intensities, and placements of the γ rays assigned to the decay of ^{78}Zn are given in Table I.

Two large-volume Ge(Li) detectors in 180° geometry were used for γ-γ coincidence measurements. Constant fraction timing was used with an acceptance window of 60 ns. Beam deposition and counting occurred simultaneously, with the source replenished every 60 s to avoid buildup from long-lived activities. The γ-γ coincidence run lasted 27 h and 3×10^6 events were recorded. Coincidence events were stored in a buffered memory

TABLE I. Photopeaks observed in the decay of 1.47-s ^{78}Zn.

Energy (keV)	Relative γ intensity[a]	Levels in ^{78}Ga (keV)	Energy (keV)	Relative γ intensity[a]	Levels in ^{78}Ga (keV)
60.243 ± 0.028	59 ± 4	341.60 – 281.35	749.70 ± 0.23	88 ± 11	1031.05 – 281.35
92.15 ± 0.07	13.5 ± 2.5	727.70 – 635.57	762.1 ± 0.8	12 ± 7	1397.78 – 635.57
112.292 ± 0.029	78 ± 6	453.89 – 341.60	788.2 ± 0.5	27 ± 8	2654.82 – 1866.52
119.361 ± 0.023	127 ± 7	979.69 – 860.33	797.6 ± 0.9	13 ± 8	3424.5 – 2626.8
132.68 ± 0.13	16 ± 6	860.33 – 727.70	808.04 ± 0.25	76 ± 11	2205.61 – 1397.78
170.71 ± 0.09	39 ± 8	1031.05 – 860.33	818.37 ± 0.23	42 ± 6	1866.52 – 1048.16
172.53 ± 0.07	60 ± 9	453.39 – 281.35	860.30 ± 0.17	559 ± 24	860.31 – 0.0
181.68 ± 0.05	640 ± 30	635.57 – 453.89	909.05 ± 0.24	51 ± 8	1866.52 – 957.55
187.81 ± 0.07	53 ± 7	1048.16 – 860.33	957.84 ± 0.29	29 ± 5	957.55 – 0.0
224.75 ± 0.06	1000 ± 30	860.33 – 635.57	979.76 ± 0.19	151 ± 13	979.69 – 0.0
262.21 ± 0.19	67 ± 6	1122.52 – 860.33	1006.20 ± 0.19	198 ± 14	1866.52 – 860.33
275.3 ± 0.8[b]	19 ± 9	1397.78 – 1122.52	1157.3 ± 0.6	18 ± 7	2205.61 – 1048.16
281.34 ± 0.18	375 ± 22	281.35 – 0.0	1174.3 ± 0.9	60 ± 30	2205.61 – 1031.05
303.38 ± 0.19	74 ± 7	1031.05 – 727.70	1345.24 ± 0.18	113 ± 9	2205.61 – 860.33
321.93 ± 0.20	75 ± 8	957.55 – 635.57	1558.0 ± 1.1	7 ± 5	3424.5 – 1866.52
342.2 ± 0.6	62 ± 23	341.60 – 0.0	1570.0 ± 0.4	26 ± 7	2205.61 – 635.57
343.93 ± 0.25	88 ± 27	979.69 – 635.57	1623.9 ± 0.9	9 ± 6	2654.82 – 1031.05
354.22 ± 0.28	166 ± 26	635.57 – 281.35	1675.2 ± 0.3	30 ± 6	2654.82 – 979.69
386.20 ± 0.22	42 ± 7	727.70 – 341.60	1926.9 ± 0.7	16 ± 7	2654.82 – 727.70
395.48 ± 0.23	18 ± 4	1031.05 – 635.57	1970.3 ± 0.6	15 ± 6	2831.1 – 860.33
413.07 ± 0.29[b]	19 ± 4	1048.16 – 635.57	2026.8 ± 0.4	27 ± 7	3424.5 – 1397.78
440.5 ± 0.7[b]	22 ± 11	1397.78 – 957.55	2103.6 ± 0.6	18 ± 10	2831.1 – 727.70
446.3 ± 0.3	23 ± 6	727.70 – 281.35	2205.66 ± 0.29	109 ± 11	2205.61 – 0.0
453.93 ± 0.15	449 ± 21	453.89 – 0.0	2489.4 ± 0.6	18 ± 6	2831.1 – 341.60
537.58 ± 0.20	23 ± 3	1397.78 – 860.33	2563.9 ± 0.9	22 ± 8	3424.5 – 860.33
635.56 ± 0.16	475 ± 24	635.57 – 0.0	2626.7 ± 0.6	22 ± 7	2626.8 – 0.0
722.8 ± 0.4	17 ± 5	3554.0 – 2831.1	2693.6 ± 0.6	24 ± 7	3554.0 – 860.33
727.0 ± 0.6[b]	19 ± 9	727.70 – 0.0	3553.9 ± 1.1	30 ± 10	3554.0 – 0.0
744.1 ± 0.5	21 ± 8	1866.52 – 1122.52			

[a] Intensity conversion factor is 0.0437 per 100 decays.

[b] E_γ and I_γ determined in γ-γ coincidence spectra.

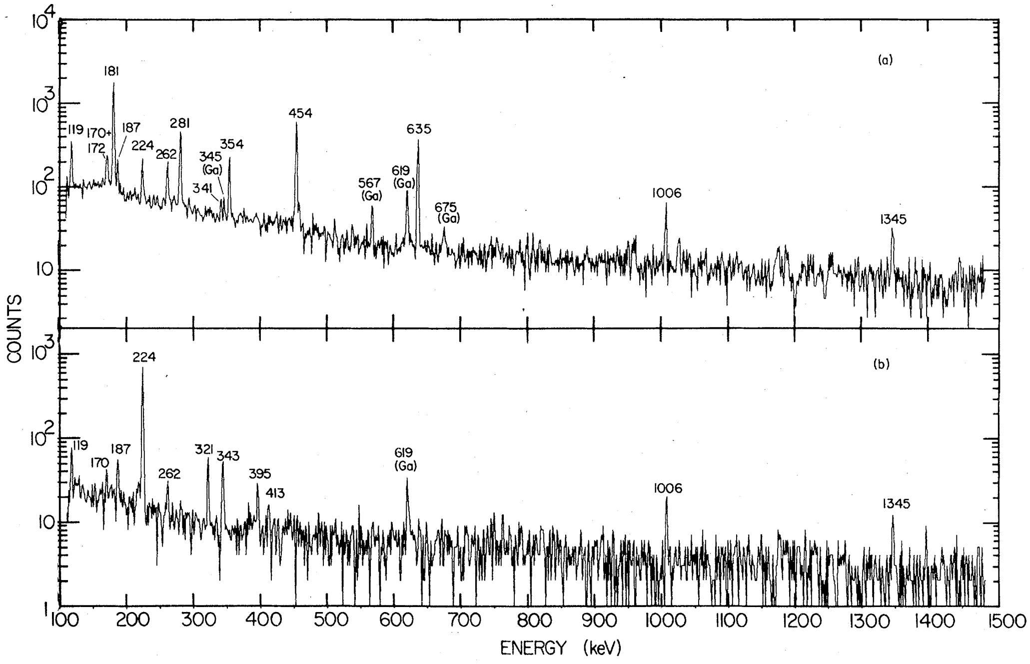

FIG. 4. γ-γ coincidence spectra for (a) 224-keV and (b) 635-keV γ rays of ^{78}Zn. (Spectra shown have not been corrected for ^{78}Ga, Compton, or chance events.)

and periodically transferred to magnetic tape. A 4096 × 4096 channel array was used. Spectra in coincidence with selected peak and background gates were reconstructed by computer. Coincidence relationships were determined by visual comparison of peak- and background-gated spectra. For a few γ rays, energies and/or intensities were determined from coincidence spectra, as indicated in Table I. Sample gated spectra for the 224- and 635-keV γ rays are shown in Fig. 4. The coincidence results are summarized in Table II.

III. DECAY SCHEME

The γ-ray singles and coincidence measurements form the basis for the decay scheme of ^{78}Zn shown in Fig. 5. Definite coincidences are shown by filled circles and possible coincidences by open circles. Zero β branching to the ground state of ^{78}Ga was assumed in calculating log*ft* values. This assumption, based on our study[5] of the decay of ^{78}Ga, is discussed below. The β- and γ-ray intensities in Fig. 5 are normalized to 100 decays of ^{78}Zn; the conversion factor for γ-ray intensities in Table I is 0.0437. Level energy, β branching, and log*ft* values are given in Table III.

The Q_β value of 6.01 ± 0.18 MeV from Aleklett *et al.*[2] was used in our log*ft* calculations. This Q_β value was obtained from β-γ coincidence measurements. Although our study shows that the low-lying level ordering in the rudimentary decay scheme used in Ref. 2 is incorrect, the Q_β value is unchanged. In Ref. 2, all nine γ-gated β spectra taken in the ^{78}Zn Q_β measurement were found to have the same maximum β energy of about 5.15 MeV. Our decay scheme requires the same maximum β energy for all gates on γ rays depopulating the 860-keV level *or* any lower level, since we found all levels below 860 keV to have negligible β feeding. Thus proper ordering of the low-lying levels does not change the Q_β value of 6.01 MeV.

The ground state of ^{78}Ga is given in Fig. 5 as (3^+). This assignment is based on our studies of the decays of both ^{78}Ga and ^{78}Zn. From the ^{78}Ga decay study,[5] the allowed or first-forbidden character of the β branches to the well-established 2_1^+ and 4_1^+ levels in ^{78}Ge restricts the ground-state J^π of ^{78}Ga to 2^-, $3^\pm$, or 4^-. The logf_1t values for these two branches were found to be about 8.5, hence just at the limiting value for excluding first-forbidden unique β transitions according to the empirical rules of Raman and Gove.[6] From these two β branches one could not rule out the 2^- or 4^- possibilities. However, β branches to other, less well-established 2^+ and 4^+ levels were found[5] to have logf_1t values around 8.1. Thus the β decay of ^{78}Ga to levels in ^{78}Ge favors $J = 3$ for the ground state of ^{78}Ga. The argument favoring 3^+ over 3^- is presented below.

Nine levels in ^{78}Ga were found to have log*ft* values less than 5.9. As indicated in Fig. 5, these

TABLE II. Coincidences observed in the decay of ^{78}Zn.

γ gate (keV)	Definite coincident γ rays (keV)	Possible coincident γ rays (keV)
119	224, 635, 860	181
170 + 172	112, 181, 187, 224, 281, 321, 386, 446, 453, 635, 860, 1174	119, 354, 727, 808, 818, 1006
181	60, 112, 119, 170 + 172, 224, 262, 281, 321, 342 + 343, 395, 413, 453, 537, 909, 1006, 1174, 1345	92, 187, 808, 1157, 1970
187	112, 181, 224, 281, 354, 635, 818, 860, 1157	446, 453
224	112, 119, 170 + 172, 181, 187, 262, 281, 342 + 343, 354, 453, 537, 635, 722, 744, 808, 818, 1006, 1174, 1345	275, 1157
262	224, 281, 354, 453, 635, 744, 808, 1970	112, 170 + 172, 181, 275, 386
281	60, 112, 119, 170 + 172, 181, 187, 224, 303, 321, 354, 386, 446, 749, 818, 909, 1006, 1174, 1345	132, 262, 808, 1157
303	92, 281, 342 + 343, 386, 446, 727, 1174	181, 453, 635
321	112, 170 + 172, 181, 354, 440, 453, 635, 808, 909	281
342 + 343	112, 181, 187, 281, 303, 354, 386, 453, 635, 1006	170 + 172, 342 + 343, 808, 818, 1345
354	92, 224, 262, 281, 321, 1006, 1345	119, 395, 762, 818, 1174
386	60, 281, 303, 342 + 343, 1174	170 + 172, 187, 537, 1006
395	170 + 172, 181, 281, 635	1174
446	170 + 172, 281, 303, 1174	119
453	92, 119, 181, 187, 224, 262, 321, 342 + 343, 395, 808, 909, 1006, 1174, 1345	
537	181, 224, 281, 808, 860	453
635	92, 119, 170 + 172, 187, 224, 262, 321, 342 + 343, 395, 413, 537, 808, 818, 909, 1006, 1174, 1345	275, 744, 762
727	303	
744	262	
749	281, 1174	
808	170 + 172, 181, 281, 342 + 343, 354, 453, 537, 762	224, 275, 635
818	187, 224, 281, 413, 635	453, 860
860	119, 170 + 172, 187, 262, 744, 1006, 1345	537, 808, 818
909	181, 281, 321, 453, 635, 957	224, 860
957	909	440
979		808
1006	170 + 172, 181, 224, 281, 354, 453, 635, 860	386
1158	187	
1174	170 + 172, 181, 224, 281, 303, 395, 635, 749	386, 453, 860
1345	181, 224, 453, 635, 860	
1558		181, 860, 1006
1970	635	224

levels have been assigned J^{π} values of 1^+. The relative intensities of γ rays depopulating these 1^+ levels are incompatible with 3^- for the ^{78}Ga ground state if we assume that γ transitions of $M2$ multipolarity very rarely compete with $E1$ or $M1/E2$ multipolarities. Consider, for example, the 1^+ level at 2205 keV, which is depopulated by six transitions, of which three go to other 1^+ levels and are thus of $M1/E2$ multipolarity. If the ground-state J^{π} were 3^-, then the 2205-keV transition would be $M2/E3$ and its observed intensity could only be explained by invoking strong $M2$ enhancement and/or strong $M1/E2$ hinderances. No such problem arises with a 3^+ assignment; thus we strongly favor 3^+ for the ground state of ^{78}Ga.

For levels other than the 1^+ levels, J^{π} assignments were proposed on the following bases. For levels with appreciable β branching, the logft and logf_1t rules of Raman and Gove[6] were used to restrict the J^{π} possibilities. Additional restrictions were obtained with the assumption that the multipolarities of γ transitions are $E1$ or $M1/E2$. (For the 341-keV level the J^{π} range was further narrowed by eliminating pure $E2$ multipolarity for the

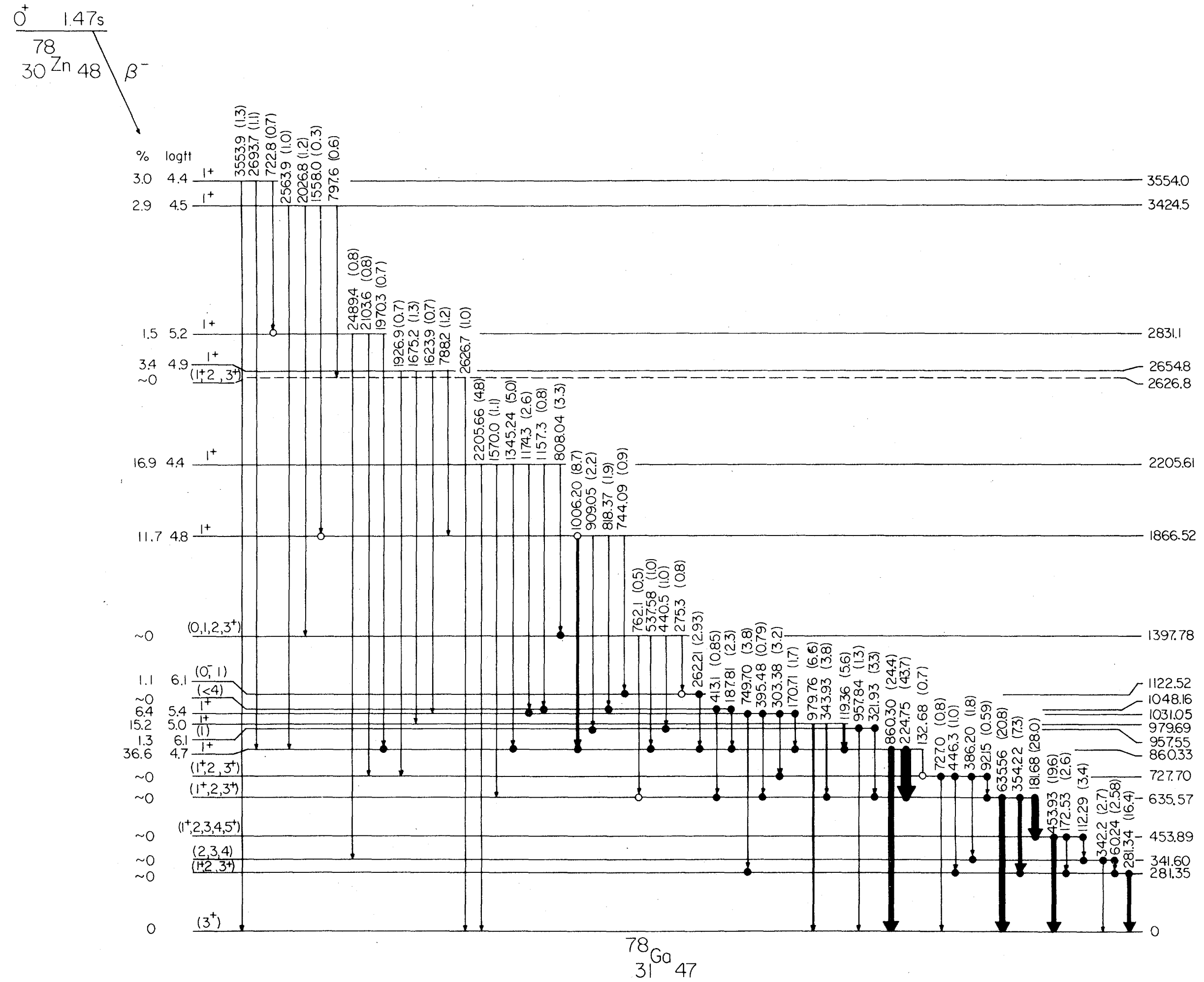

FIG. 5. ^{78}Ga level scheme from β^- decay of 1.47-s ^{78}Zn.

60.2-keV transition due to the large $E2$ internal conversion coefficient of 4.6, which would require large negative β feeding to this level.) The resulting J^π values shown in Fig. 5 made use of the 1^+ and ground-state (3^+) assignments; it should be noted, however, that not all assignments to other levels are mutually compatible. For example, the $(1^+, 2, 3^+)$ range for the 635-keV level is compatible, according to the preceding bases, with the 1^+ level at 860 keV and the (3^+) ground state, but not with all of the J^π values shown for the 453-keV level. Only the 1^+ assignments are shown in Fig. 5 without parentheses, as we consider the other J^π assignments to be tentative. In addition, one should also regard as somewhat tentative the 1^+ assignments to levels with β branches of only a few percent, since the logft values could rise above 5.9 if relatively weak γ rays, unobserved by us in this work, were later found to populate these levels.

The decay scheme in Fig. 5 is not only more complete than the level scheme of Matsushigue and Matsushigue quoted in Ref. 2, but is also different for all levels below 860 keV. Our ordering is supported by our γ-γ coincidence data. For example, consider the gated spectra of Fig. 4, in which the 321-, 343-, and 395-keV γ rays are clearly seen to be in coincidence with the 635-keV γ ray but not the 224-keV γ ray. These spectra are inconsistent with the placements of 224- and 635-keV γ rays in the scheme of Matsushigue and Matsushigue quoted in Ref. 2.

IV. DISCUSSION

Inferences about the structure of odd-odd ^{78}Ga are difficult to make from this study. Nevertheless, it is useful to discuss the ground-state J^π assignment of (3^+) and the strongly β-fed 1^+ levels around 1 MeV of excitation. Systematics of odd-

TABLE III. β branching and log*ft* values for ^{78}Zn decay.

Level energy (keV)	β branching (%)	log*ft* [b]
0 ± 0	0 ± 0 [a]	
281.35 ± 0.08	~0 ± 1.6	
341.60 ± 0.08	~0 ± 1.4	
453.89 ± 0.08	~0 ± 1.6	
635.57 ± 0.07	~0 ± 2.6	
727.70 ± 0.09	~0 ± 0.9	
860.33 ± 0.08	36.6 ± 2.2	4.7
957.55 ± 0.15	1.3 ± 0.7	6.1
979.69 ± 0.08	15.2 ± 1.4	5.0
1031.05 ± 0.10	6.4 ± 1.5	5.4
1048.16 ± 0.10	~0 ± 0.6	
1122.52 ± 0.18	1.1 ± 0.6	6.1
1397.78 ± 0.16	~0 ± 0.9	
1866.52 ± 0.13	11.7 ± 0.9	4.8
2205.61 ± 0.13	16.9 ± 1.6	4.4
2626.8 ± 0.5	~0 ± 0.5	
2654.8 ± 0.3	3.4 ± 0.6	4.9
2831.1 ± 0.3	1.5 ± 0.6	5.2
3424.5 ± 0.3	2.9 ± 0.6	4.5
3554.0 ± 0.6	3.0 ± 0.5	4.4

[a] Ground-state β branching of 0 used in log*ft* calculation.

[b] Q_β value of 6.01 ± 0.18 MeV was taken from Ref. 2.

odd Ga nuclei, neighboring odd-*A* Ga isotopes, and odd-*A* $N = 47$ isotones are presented below and discussed to the extent that they relate to ^{78}Ga. Unless explicitly stated otherwise, the primary reference used for these nuclei is the compilation of Lederer and Shirley.[7]

The J^π values of odd-odd Ga nuclei are ^{62}Ga (0^+); ^{64}Ga, 0^+; ^{66}Ga, 0^+; ^{68}Ga, 1^+; ^{70}Ga, 1^+; ^{72}Ga, 3^-; ^{74}Ga $(4)^-$; ^{76}Ga (3^-); and, from this work, ^{78}Ga (3^+). For $^{62-68}$Ga the ground-state J^π values can be adequately explained in terms of the odd proton and the odd neutron both in $1f_{5/2}$ and $2p_{3/2}$ spherical shell-model orbitals. For $N \geq 41$, neutrons are beginning to fill the $2p_{1/2}$ and $1g_{9/2}$ orbitals. The latter orbital, with positive parity, enters the picture at ^{72}Ga. Negative parities for odd-odd Ga isotopes with $N > 41$ are predicted by the spherical shell model. The positive parity assignment for ^{78}Ga thus departs from the ground-state J^π predictions of a spherical independent-particle shell model. (As is discussed below, there is a possibility that ^{76}Ga may also be 3^+, hence it also departs from such simple predictions.) Possible couplings which explain this deviation are best discussed after considering the systematics of neighboring odd-*A* nuclei.

Ground-state J^π values of $\frac{3}{2}^-$ are assigned to odd-*A* Ga isotopes with $A = 65$, 67, 69, 71 and tentatively assigned for $A = 73$ and 75. For ^{77}Ga, a $(\frac{3}{2}^-)$ assignment is consistent with the observation[8] that 50% of the β decay of ^{77}Ga directly populates the $\frac{1}{2}^-$ isomeric state of ^{77}Ge. For ^{79}Ga, β strength function measurements[8] and the level scheme[2] favor a J^π of $\frac{3}{2}^-$. Thus $\frac{3}{2}^-$ is the favored assignment for all known odd-*A* Ga isotopes. Very little is known about excited-state J^π values for neutron-rich odd-*A* Ga isotopes, but simple shell-model considerations lead one to expect a low-lying $\frac{5}{2}^-$ state and, at higher energies, $\frac{1}{2}^-$ and $\frac{9}{2}^+$ single-particle states. For neighboring odd-*A* As isotopes, the $\frac{9}{2}^+$ states generally occur at excitation energies of about 0.5 MeV or slightly lower.

The systematics of odd-*A* $N = 47$ isotones reveals a low-lying $\frac{7}{2}^+$ state not expected from simple spherical shell-model considerations. In ^{81}Se, which has a $(\frac{1}{2})^-$ ground state and a $(\frac{9}{2})^+$ state at 294 keV, the $(\frac{7}{2})^+$ state occurs at 103 keV. For ^{83}Kr, ^{85}Sr, and ^{87}Zr, the ground states are $\frac{9}{2}^+$ and the $\frac{7}{2}^+$ states occur at energies of about 0.2 MeV or less, below the $\frac{1}{2}^-$ states. For ^{79}Ge, Q_β measurements[2,9] indicate that the 42-s $(\frac{1}{2})^-$ isomer and the 19-s $(\frac{7}{2}^+, \frac{9}{2}^+)$ isomer are probably within 0.2 MeV in energy. In addition to the low-lying $\frac{1}{2}^-$, $\frac{7}{2}^+$, and $\frac{9}{2}^+$ states, $\frac{3}{2}^-$ and $\frac{5}{2}^-$ states are observed at about 0.5 MeV in ^{81}Se and ^{83}Kr. Except for the $\frac{7}{2}^+$ states, the other states are expected from spherical shell-model considerations.

The preceding summary of low-lying states of odd-*A* nuclei near odd-odd ^{78}Ga can be used to predict, via extreme weak coupling, low-lying levels in ^{78}Ga. Under about 0.5 MeV of excitation, states due to coupling a $\frac{3}{2}^-, \frac{5}{2}^-$ proton to a $\frac{1}{2}^-, \frac{7}{2}^+, \frac{9}{2}^+$ neutron are expected. Only one such coupling, $\pi(\frac{5}{2}^-) \otimes \nu(\frac{1}{2}^-)$, could yield the proposed 3^+ ground state. Also only one coupling, $\pi(\frac{3}{2}^-) \otimes \nu(\frac{1}{2}^-)$, could yield a 1^+ state. Under about 1 MeV of excitation, the proton states $\frac{1}{2}^-, \frac{9}{2}^+$ and neutron states $\frac{3}{2}^-, \frac{5}{2}^-$ should also be considered. With the addition of these states, there are eight additional possibilities for forming 1^+ states in ^{78}Ga, with the neutron $\frac{7}{2}^+$ state involved in only one of the nine simple weak couplings.

Not only is the number of 1^+ states observed in the decay of ^{78}Zn reasonable, but the low log*ft* values of some of these states are also to be expected. The configurations (relative to a "doubly magic" ^{78}Ni core) $\pi p_{3/2}{}^2 \nu g_{9/2}{}^{-2}$ and $\pi f_{5/2}{}^2 \nu g_{9/2}{}^{-2}$ should give significant terms to the 0^+ ground state of ^{78}Zn. Each of these terms can connect to simple 1^+ states in ^{78}Ga via the Gamow-Teller decays $\nu p_{1/2} \rightarrow \pi p_{3/2}$ or $\nu p_{3/2} \rightarrow \pi p_{1/2}$ as well as the Fermi decays $\nu p_{1/2} \rightarrow \pi p_{1/2}$ or $\nu p_{3/2} \rightarrow \pi p_{3/2}$. For example, the seniority-zero term $\pi p_{3/2}{}^2 \nu g_{9/2}{}^{-2}$ in ^{78}Zn can undergo a Gamow-Teller decay to the 1^+ seniority-two term $\pi p_{3/2}{}^3 \nu g_{9/2}{}^{-2} p_{1/2}$ in ^{78}Ga. The number of low log*ft* decays is consistent with the four

Gamow-Teller and four Fermi β decay mechanisms available to simple 1^+ states in ^{78}Ga.

Since a J^π of 3^+ for the ^{78}Ga ground state departs from the systematics of lower-mass Ga nuclides in which the parities are negative, we have reexamined the assignment of 3^- for the ^{76}Ga ground state. For the Ga decay,[10] the logft values for the 2^+ and 4^+ states below 2 MeV restrict the ^{76}Ga J^π to $2^-, 3^\pm, 4^-$. However, a level at 3951 keV, tentatively assigned (2^+) in Ref. 10, has a logft value of 5.4, and hence has allowed β decay.[6] Accepting the (2^+) assignment of Ref. 10 thus leads to (3^+) for the ^{76}Ga ground state, rather than the (3^-) assignment based on systematics and the spherical shell model.[10,11]

To summarize, the preceding arguments indicate that both ^{76}Ga and ^{78}Ga have (3^+) ground states, hence they depart from the systematics of lighter odd-odd Ga isotopes. This departure could be due to effects from deformation and/or pairing. These speculations must be regarded as tentative because of the nature of some of the arguments made and the J^π values of some of the levels involved. A deeper understanding of the structure of nuclei in this region probably will not be obtained until additional information on both neighboring odd-N and odd-Z neutron-rich nuclei is available.

ACKNOWLEDGMENTS

This study was supported by the U. S. Department of Energy, Division of Basic Energy Sciences, under Contract No. W-7405-eng-82. We owe a special appreciation to W. L. Talbert, Jr., who was primarily responsible for the design of the in-beam ion source. We also acknowledge the efforts of R. L. Gill, A. R. Landin, and M. A. Cullison who effectively maintained the TRISTAN system at Ames while this work was in progress.

---

[1] D. A. Lewis, John C. Hill, and F. K. Wohn, Bull. Am. Phys. Soc. 23, 573 (1978).

[2] K. Aleklett, E. Lund, G. Nyman, and G. Rudstam, Nucl. Phys. A285, 1 (1977).

[3] J. R. McConnell and W. L. Talbert, Jr., Nucl. Instrum. Methods 128, 227 (1975).

[4] W. L. Talbert, Jr., F. K. Wohn, John C. Hill, A. R. Landin, M. A. Cullison, and R. L. Gill, Nucl. Instrum. Methods 161, 431 (1979).

[5] D. A. Lewis, John C. Hill, F. K. Wohn, and M. L. Gartner, Phys. Rev. C 22, 2178 (1980).

[6] S. Raman and N. B. Gove, Phys. Rev. C 7, 1995 (1973).

[7] *Table of Isotopes*, 7th ed., edited by C. M. Lederer and V. Shirley (Wiley, New York, 1978).

[8] K. Aleklett, G. Nyman, and G. Rudstam, Nucl. Phys. A246, 425 (1975).

[9] M. Karras, T. E. Ward, and H. Ibochi, Nucl. Phys. A147, 120 (1970).

[10] D. C. Camp and B. P. Foster, Nucl. Phys. A177, 401 (1971).

[11] F. E. Bertrand and R. L. Auble, Nucl. Data Sheets 19, 507 (1976).