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BRIEF REPORTS

Brief Reports are short papers which report on completed research or are addenda to papers previously published in the **Physical Review**. *A Brief Report may be no longer than $3\frac{1}{2}$ printed pages and must be accompanied by an abstract.*

Structure of odd-odd ^{74}Ga from the decay of neutron-rich ^{74}Zn

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A decay scheme of ^{74}Zn to levels in ^{74}Ga is presented in which 39 γ rays are placed, deexciting 11 states up to 1085 keV. Five levels are postulated to have $J^{\pi}=1^{+}$ based on β feedings but much uncertainty still exists concerning J^{π} assignments for levels below 300 keV.

In a recent study[1] of the decay of ^{74}Cu, a number of γ rays were observed from the decay of the daughter nucleus ^{74}Zn. The data obtained were sufficient to considerably extend the known information on the decay scheme of ^{74}Zn to levels in odd-odd ^{74}Ga.

The decay of ^{74}Zn was first reported by Erdal *et al.*[2] from experiments at the ISOLDE separator. The most complete study of ^{74}Zn decay is that of Runte *et al.*[3] in which ^{74}Zn was produced by the $^{\mathrm{nat}}W$ (^{76}Ge, ^{74}Zn) X reaction and mass separated. A total of 19 γ rays from ^{74}Zn decay were observed of which 16 were placed in a level scheme for ^{74}Ga with 9 excited states up to 894 keV. The Nuclear Data Group[4] has evaluated the ^{74}Zn half-life to be 96 s based on the average of a number of measurements. Van Klinken and Taft[5] have studied the decay of the 59-keV isomeric level in ^{74}Ga and measured its half-life to be 9.5 s. No information is available[4] on excited levels in ^{74}Ga observed in reaction studies.

The sources of ^{74}Zn were obtained from the $A=74$ mass-separated beam produced by the TRISTAN facility operating on line to the High-Flux Beam Reactor at Brookhaven National Laboratory. The target was 4 g of enriched ^{235}U in a high-temperature plasma ion source.[6] The target neutron flux was 3×10^{10} $n/\mathrm{cm}^2\,\mathrm{s}$ and the $A=74$ ion beam contained isotopes of Cu, Zn, and Ga. There was no evidence for cross contamination from adjacent masses, but a number of γ rays were observed from decay of nuclei in the $A=148$ mass chain due to doubly charged ions in the mass-separated beam.

Measurements of γ-ray singles spectra were made using three separate detector configurations. In each case, two detectors observed the point of beam deposit in a 180° geometry. In a survey run of 1.5 d, two HpGe detectors were used with two time cycles (22 s growth with 10 s decay, and 4 s growth with 2 s decay). The spectra from these two cycles were added to obtain good statistics for both the short- and long-lived components. In a second run of 4.1 d, a time cycle of 3 s growth was used to enhance the short-lived ^{74}Cu. Finally, a combination of a low-energy photon spectrometer (LEPS) and a HpGe detector was used to study the low-energy transitions using two time cycles (3s growth for 4.5 d, and 190 s growth with 10 s decay for 1.1 d). In each case, background suppression was obtained by gating the analog-to-digital converters (ADC's) with pulses from β rays detected in a thin plastic scintillator. These measurements made it possible to distinguish ^{74}Zn γ rays from those of the short-lived ^{74}Cu, long-lived ^{74}Ga, and the various members of the $A=148$ decay chain. Simultaneous to the singles measurements, β-gated $\gamma\gamma$ coincidences were taken using a standard fast coincidence system. A representative γ-ray singles spectrum from one of the HpGe detectors covering the energy range from 40 to 1200 keV is shown in Fig. 1.

The energy calibration was performed internally in each spectrum using well-known γ rays from ^{74}Ga decay and from the $A=148$ chain. The detector efficiencies were determined using a standard calibration source placed at the position of beam deposit. The γ-ray energies and intensities were determined using a weighted average of results from three spectra: the two LEPS measurements and one HpGe survey spectrum. The γ-ray intensities within each spectrum were corrected for coincidence summing effects prior to obtaining the weighted average. The $\gamma\gamma$ coincidence information was analyzed using a time window of at least 165 ns so that the 31 ns

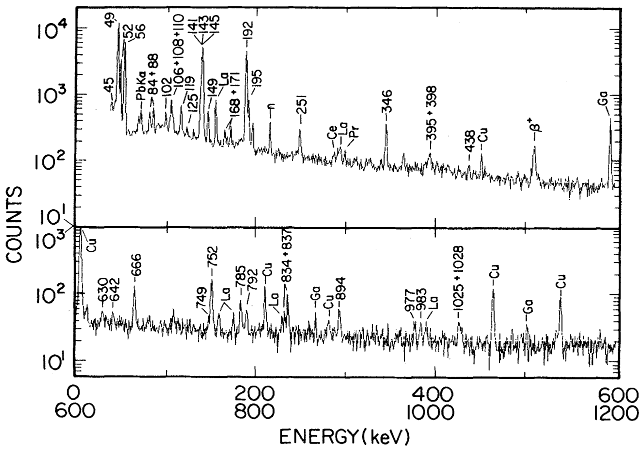

FIG. 1. γ-ray singles spectrum from a mass-separated $A=74$ source. Peaks assigned to ^{74}Zn decay are labeled by their energies in keV. Peaks following other decays are labeled as follows: ^{74}Cu (Cu), ^{74}Ga (Ga), ^{148}La (La), ^{148}Ce (Ce), ^{148}Pr (Pr). The peak labeled "n" is probably from the decay of ^{73}Zn fed by delayed neutron emission of ^{74}Cu.

half-life of the 56-keV level would not distort the final results. The γ energies, relative intensities, placements, and coincidence relationships are summarized in Table I.

The decay scheme for ^{74}Zn to levels in ^{74}Ga, based on γ singles and $\gamma\gamma$ coincidence measurements, is shown in Fig. 2. A total of 39 γ rays were placed in the ^{74}Ga level scheme depopulating 11 excited states up to 1085-keV excitation energy. This more than doubles the number of placed[4] γ rays. The level scheme presented here is in good agreement with the work of Runte *et al.*[3] with additional levels postulated at 102 and 1085 keV. These levels are firmly established by both energy sums and coincidences. These results do not support the existence of levels at 752 and 775 keV postulated by Singh and Viggars[4] since the 141- and 227-keV levels (first suggested by Runte *et al.*[3]) are definitely established by multiple γ rays depopulating these levels. The placement of the relevant γ rays (666 and 752 keV) are supported by $\gamma\gamma$ coincidence data given in Table I.

The $\log ft$ values for β decay to levels in ^{74}Ga were calculated using $Q_\beta = 2.35$ MeV from the tables of Wapstra, Audi, and Hoekstra.[7] No β feeding is assumed (based on the assumptions given below) to either the ^{74}Ga ground state or the levels at 56 and 59 keV. For the purpose of determining the conversion coefficients needed for the summing corrections and level feedings, the transitions were assumed to be either $M1$ or $E1$ in character. The exact assignment was not important since for $Z=31$ at low energies $\alpha(M1) \approx \alpha(E1)$. Exceptions to this were the 108-, 251-, and 894-keV transitions (which may be due completely to "summing-in" effects and are dashed in the level scheme) and the 56-keV transition. For the 56-keV transition, a 2.6% admixture of $E2$ is assumed based on the upper limit of van Klinken and Taft.[5] This assumption has negligible effect on the summing corrections and indicates that only a small amount of unobserved intensity feeding the 56-keV level would assure no β feeding.

The largest summing correction was for the 56-keV γ ray (107.2 ± 1.2 uncorrected vs 120 ± 3 corrected). This correction was relatively unaffected by the assumption of $E1$, $M1$, or $M1$ plus small $E2$ admixtures for internal

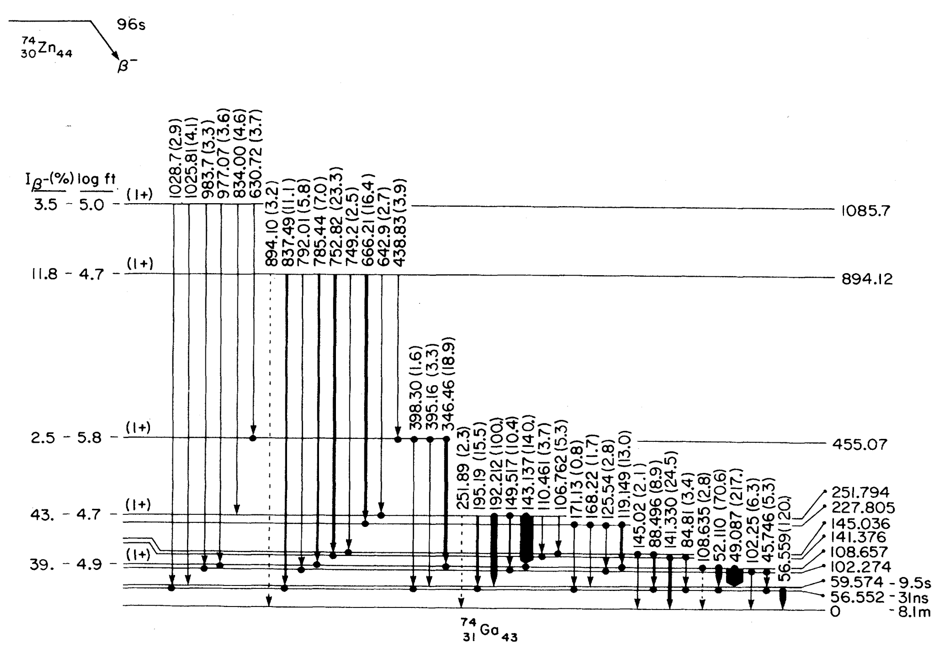

FIG. 2. Decay scheme for ^{74}Zn ($T_{1/2}=96$ s) to ^{74}Ga ($T_{1/2}=8.1$ m). Numbers in parentheses indicate γ-ray intensities not corrected for internal conversion. β intensities and $\log ft$ values are shown only for levels with β feeding greater than 2%.

conversion. The correction for the 56-keV γ ray was exaggerated since the change for the standard 192-keV ($I_\gamma=100$) γ ray was in the opposite direction. $\log ft$ values in Fig. 2 are shown for levels with a β branching greater than 2%. Four levels have $\log ft$ values ≤ 5.0, indicating a J^π of 1^+, while the 455-keV level has a $\log ft$ of 5.8 implying a J^π of 1^+ but with less certainty. $J^\pi=0^+$ is excluded[8] for such low $\log ft$ values.

The absence of a transition between the 59-keV level and the ground state,[5] along with the measured half-lives for the 56- and 59-keV levels[5] and β feeding[4] from the ^{74}Ga ground state to the 2_1^+ and 4_1^+ states in ^{74}Ge, have led to two proposals for the sequence of J^π values for the lowest three levels in ^{74}Ga. They are (starting with the ground state) $(4)^-$, (3^-), and (1^+) by van Klinken and Taft[5] and (3^-), (2), and 0 by the Nuclear Data Group.[4]

TABLE I. γ transitions observed in ^{74}Zn decay.

E_γ(keV)[a]	I_γ[b]	Levels (keV) initial to final	Coincident[c] γ rays (keV)
45.746±0.017	5.3±0.4	102-56	56,125,149,792
49.087±0.010	217.0±5.0	108-59	119,143,346,438,630,666,785
52.110±0.014	70.6±0.8	108-56	56,119,143,346,666,785
56.559±0.010	120.0±3.0[d]	56-0	45,52,84,88,106,119,125,143 149,171,195,346,398,630,666, 749,785,792,837,983,1028
84.81±0.03	3.4±0.5	141-56	56,(110),752
88.496±0.024	8.9±0.8	145-56	56,106,749
102.25±0.03	6.3±0.5	102-0	125,149,666,792,983
106.762±0.022	5.3±0.8	251-145	56,88,145
108.635±0.020	2.8±2.1	108-0	119,143
110.461±0.024	3.7±0.3	251-141	141
119.149±0.020	13.0±1.1	227-108	49,52,56,666
125.54±0.03	2.8±0.5	227-102	56,102,666
141.330±0.021	24.5±1.9	141-0	110,752
143.137±0.024	140.±4.0	251-108	49,52,56,108,642
145.02±0.04	2.6±0.2	145-0	106,749
149.517±0.024	10.4±0.6	251-102	45,56,102
168.22±0.06	1.7±0.2	227-59	666
171.13±0.07	0.8±0.2	227-56	56,666
192.212±0.019	100.0±2.0	251-59	642
195.19±0.04	15.5±1.1	251-56	56
251.89±0.05	2.3±1.3	251-0	
346.46±0.05	18.9±1.0	455-108	49,52,56,438,630
395.16±0.13	3.3±0.4	455-59	
398.30±0.25	1.6±0.4	455-56	56
438.83±0.17	3.9±0.7	894-455	49,52,56,346,395,398
630.72±0.12	3.7±0.7	1085-455	49,52,56,346,395
642.9±0.3	2.7±0.6	894-251	143,149,192
666.21±0.10	16.4±1.9	894-227	49,56,102,119,125,168,171
749.2±0.3	2.5±0.6	894-145	56,88,145
752.82±0.07	23.3±1.7	894-141	56,84,141
785.44±0.12	7.0±0.8	894-108	49,52,56,108
792.01±0.16	5.8±0.7	894-102	45,56,102
834.00±0.24	4.6±0.8	1085-251	
837.49±0.11	11.1±0.7	894-56	56
894.10±0.13	3.2±0.4	894-0	
977.07±0.24	3.6±0.7	1085-108	49,56
983.7±0.3	3.3±0.8	1085-102	56,102
1025.81±0.23	4.1±0.7	1085-59	
1028.7±0.4	2.9±0.7	1085-56	56

[a]Weighted average of γ-ray energies from various spectra.
[b]Weighted average of γ-ray intensities from various spectra. Intensities normalized to 100 for the 192-keV γ ray.
[c]All γ-γ coincidences are considered to be definite, except for one possible coincidence which is enclosed in parentheses.
[d]The intensity does not include feeding from the 59-keV level since the γ spectrum was β gated (see the text).

Both assignments have $\Delta J=3$ for ground-state decay of the 59-keV level, which is consistent with the 9.5 s half-life for that level. We favor the assignments of the Nuclear Data Group.[4] The strong β feeding to the 108-keV level and the strength of the 49- and 52-keV γ rays favors a 1^+ assignment for the 108-keV level and limits J to 0, 1, and 2 for either the 56- or the 59-keV levels. Absence of a 59-keV γ ray along with no β feeding to the 59-keV level favors $J=0$ rather than $J^\pi=1^+$ for the level.

The use of the β gate allows us to measure the intensity of the 56-keV transition independent of the presence of the 59-keV ^{74}Ga isomer, since the conversion electrons from the 3-keV transition are too low in energy to be included in our β gate. It would be of interest to compare our results with those from an ungated γ singles measurement, but such a measurement was, for us, not possible due to the low intensity of the $A=74$ beam.

In conclusion, we have studied the decay of ^{74}Zn to levels in ^{74}Ga. New levels have been postulated at 102 and 1085 keV, and the number of transitions placed in the level scheme has more than doubled. Of the 12 states observed in ^{74}Ga, five are populated by allowed β transitions and probably have $J^\pi=1^+$. Odd-A nuclei with $Z=31$ or $N=43$ have low-lying (≤ 0.6 MeV) $\frac{1}{2}^-$, $\frac{3}{2}^-$, and $\frac{5}{2}^-$ states that are associated with $p_{1/2}$, $p_{3/2}$, and $f_{5/2}$ nucleons. Thus below ~ 1 MeV, one could expect five allowed β decays to be observed in the decay of ^{74}Zn. Much uncertainty still exists concerning J^π assignments for the nine states below 300 keV.

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