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ABSTRACT

A lithium-drifted germanium detector having a resolution of 1.3 keV at 122 keV has been used to examine the gamma-ray spectrum of $^{177}Lu^{m}$. Three new transitions have been found which fit into the previous decay scheme. Gamma-ray relative intensity measurements have been used to derive many of the parameters associated with the Unified Nuclear Model. Of particular interest is the comparison of derived E1 transition probabilities to simple theory.

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The 155-day isomer of ^{177}Lu offers a good test of the Unified Model for deformed nuclei. The high spin of this isomer (23/2) permits population of high-spin members of low-lying rotational bands in both ^{177}Lu and ^{177}Hf. The succeeding intra- and inter-band transitions provide many relationships which are easily compared to theory.

Past studies of the gamma-ray spectrum emitted in the decay of this nucleus have been carried out primarily using curved-crystal spectrometers.[1,2] The rapid development of lithium-drifted germanium (Ge(Li)) detectors has allowed us to study this spectrum, taking particular advantage of the peak-to-background ratio, which is significantly better than that observed with the curved-crystal. Using a Ge(Li) detector having a resolution of 1.3 keV at 122 keV, we have found three of the expected transitions missing from the level scheme of ^{177}Hf as proposed by Alexander et al.[1] and modified by both Blok and Shirley[3] and Bodenstedt et al.[4] The decay scheme of $^{177}Lu^{m}$ from Alexander et al.[1] is shown in Fig. 1. The transitions which we have added are the 181.7-keV ($15/2 \rightarrow 13/2$, K = 7/2-band), 283.3-keV ($21/2+$ (K = 9/2) $\rightarrow 19/2-$ (K = 7/2)), and 291.3-keV ($17/2+$ (K = 9/2) $\rightarrow 15/2-$ (K = 7/2)) transitions.

We have also measured the relative intensities of all gamma rays in the above scheme, and used these values to calculate g factors and branching ratios within the rotational bands. These data are summarized in Table I.

It can be seen that the derived values are constant (within experimental error) in each band. Work is presently under way to establish the energies of those transitions above 200 keV to a greater degree of accuracy than that attained through curved-crystal measurements.

Of particular theoretical interest in ^{177}Hf is the large number of E1 interband transitions. Attempts to explain the observed transition rates of E1's in ^{177}Hf as well as other nuclei have been largely unsuccessful. However, both Refs. 5 and 6 have indicated that consideration of the rotation-particle interaction should be included in calculating absolute E1 transition probabilities for the case $\Delta K = \pm 1$.

According to the presently established level scheme of ^{177}Hf, earlier work has identified ten of the sixteen E1's ostensibly leading from the 9/2+[624] to the 7/2-[512] band. Identification of the $21/2 \rightarrow 19/2$ and $17/2 \rightarrow 15/2$ interband transitions has now been achieved. Moreover, Table II shows that improved relative intensity measurements, particularly for the 117.0 keV gamma ray, have apparently removed the only case of serious disagreement between experiment and the theoretical branching ratios obtained using the procedure followed in Ref. 5. Therefore, it has seemed valid to predict the branching ratios and thus the intensities of the four unobserved E1 transitions. As indicated in Table II, the 17.7, 40.8, and 69.0 keV E1's are in all likelihood too weak to be seen with presently available detection systems. They would have intensities of only about 0.02, 0.09, and 0.09 percent respectively, relative to the 105.4 keV gamma. Although the 88.7 keV E1 has a predicted relative intensity of 0.3%, no evidence was found to indicate its presence. Further studies are being undertaken to identify at least two of the four "missing" E1 transitions.

The additional experimental evidence found in ^{177}Hf for RPC admixed components in the E1 transition probability lends further support to this approach in explaining anomalous E1 branching ratios.

FOOTNOTES AND REFERENCES

†This work was done under the auspices of the U. S. Atomic Energy Commission.

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Table I. Branching ratios and g factors for the K = 7/2+[404]rotational band in ^{177}Lu and the K = 7/2-[514] and K = 9/2+[624] bands in ^{177}Hf. λ is the experimental crossover to cascade ratio where I is the initial spin state. $1/\delta^2$ is the M1/E2 branching ratio for I → I-1 cascade transitions. Q_0 is the intrinsic quadrupole moment for the nucleus in spin state I, and $g_K - g_R$ is associated with transitions I → I-1.

	I	λ	$[(g_K-g_R)/Q_0]^2$	$1/\delta^2$
^{177}Lu				
K = 7/2+	11/2	0.86±0.12	$(2.6\pm0.4) \times 10^{-3}$	4.0
	13/2	2.1 ±0.3	$(2.4\pm0.3) \times 10^{-3}$	4.0
	15/2	3.3 ±0.4	$(2.6\pm0.3) \times 10^{-3}$	4.3
	17/2	4.9 ±0.7	$(2.5\pm0.4) \times 10^{-3}$	4.4
^{177}Hf				
K = 7/2-	11/2	4.0 ±0.4	$(0.43^{+0.68}_{-0.43}) \times 10^{-4}$	0.077
	13/2	7.0 ±1.0	$(2.6^{+1.4}_{-1.0}) \times 10^{-4}$	0.48
	15/2	17.3 ±3.3	$(2.4^{+1.6}_{-1.1}) \times 10^{-4}$	0.45
^{177}Hf				
K = 9/2+	13/2	0.35±0.04	$(2.7\pm0.3) \times 10^{-3}$	7.8
	15/2	0.81±0.08	$(2.8\pm0.3) \times 10^{-3}$	7.6
	17/2	1.42±0.14	$(2.9\pm0.3) \times 10^{-3}$	7.8
	19/2	1.95±0.20	$(3.0\pm0.3) \times 10^{-3}$	7.5
	21/2	3.35±0.42	$(2.7\pm0.3) \times 10^{-3}$	7.4

Table II. Relative reduced strengths for transitions from the K = 9/2+ to K = 7/2- bands in ^{177}Hf.

I_i	I_f	I'_f	$\frac{I_\gamma}{I'_\gamma}$	$\frac{B(E1)\ I_i \rightarrow I_f}{B(E1)\ I_i \rightarrow I'_f}$ Experiment: This work	Experiment: Alex.[1]	Theory: Alaga[7‡]	Theory: After Vergnes (Ref. 5)
9/2	9/2	7/2	54	200	175	0.23	200*
9/2	11/2	9/2	0.014	0.35	0.37	0.10	0.48
11/2	11/2	9/2	2.8	15.4	15.8	0.41	13
11/2	13/2	11/2	(0.0008)†			0.14	0.79
13/2	13/2	11/2	0.47	4.4	7.7	0.56	3.7
15/2	15/2	13/2	0.15	2.5	20	0.70	1.9
17/2	17/2	15/2	(0.033)†			0.79	1.2
19/2	19/2	17/2	(0.011)†			0.88	0.81
21/2	21/2	19/2	(0.002)†			0.96	0.61

*Assumed to adjust parameter(s).

†Parentheses indicate theoretical ratios, in cases where one of the gamma-rays if unobserved.

‡Alaga's rule for branching between members of two rotational bands is the ratio of Clebsch-Gordan coefficients, $(I_i 1\ K_i{-}1 | I_f K_f)/(I_i 1\ K_i{-}1 | I'_f K_f)$, squared.

FIGURE CAPTION

Fig. 1. Decay scheme of $^{177}Lu^{m}$ as proposed by Alexander et al.[1] and modified by Refs. 3, 4, and the present work.

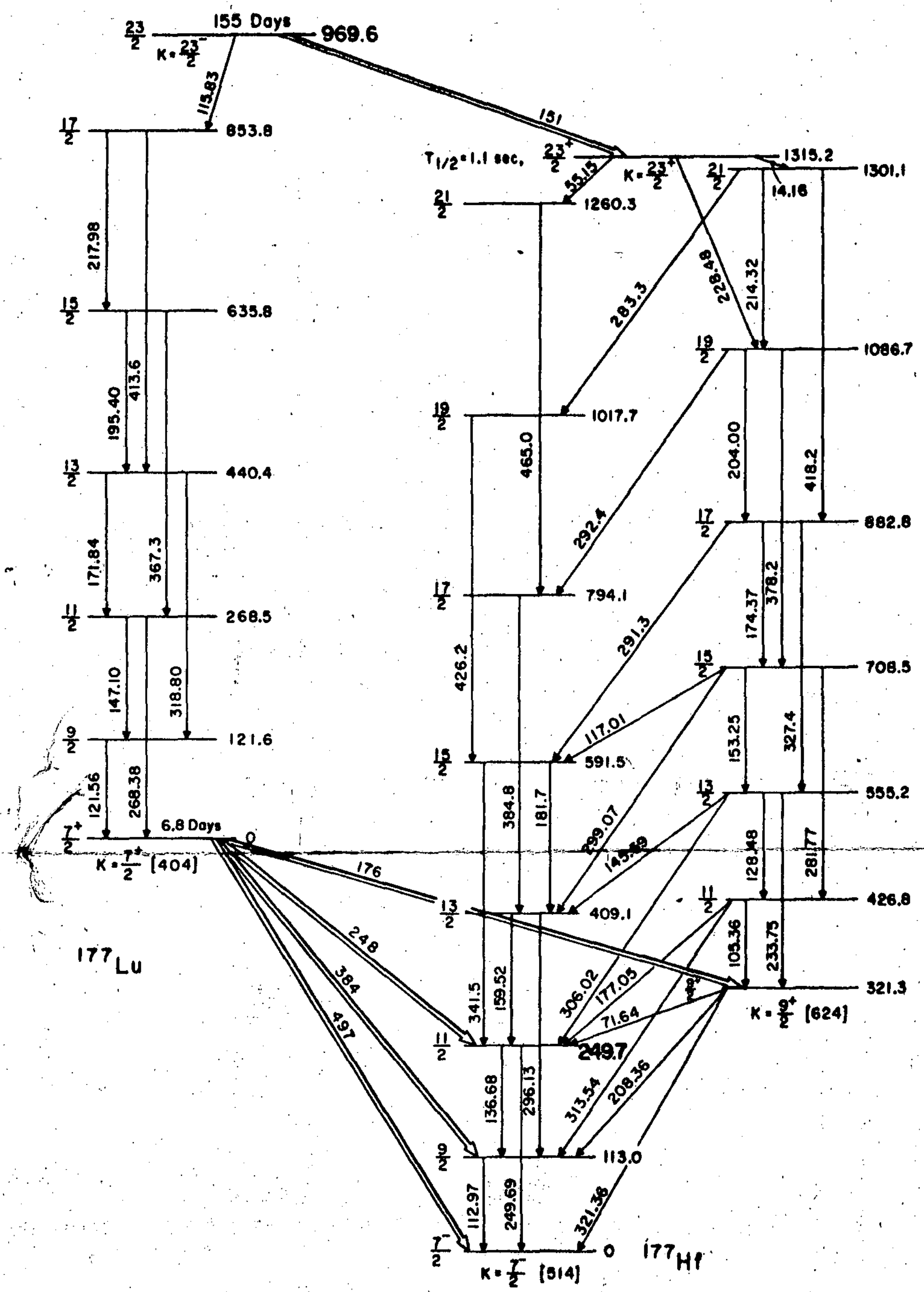
155 Days
969.6
115.83
853.8
217.98
635.8
195.40
413.6
440.4
171.84
367.3
268.5
147.10
318.80
121.6
121.56
268.38
6.8 Days
0
$K = \frac{7}{2}^+$ [404]
176
248
384
497
^{177}Lu
$T_{1/2} = 1.1$ sec.
151
1315.2
1301.1
55.15
14.16
1260.3
283.3
228.48
214.32
1086.7
1017.7
465.0
204.00
418.2
292.4
882.8
794.1
291.3
174.37
378.2
708.5
426.2
117.01
591.5
153.25
327.4
555.2
384.8
181.7
299.07
145.89
128.48
281.77
409.1
426.8
105.36
233.75
321.3
$K = \frac{9}{2}^+$ [624]
341.5
159.52
306.02
177.05
71.64
249.7
136.68
296.13
313.54
208.36
113.0
112.97
249.69
321.36
0
$K = \frac{7}{2}^-$ [514]
^{177}Hf

Fig. 1