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ISOMER RATIO CALCULATIONS USING
MODELED DISCRETE LEVELS

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We have made isomer ratio calculations for the reactions:

$^{175}\text{Lu}(n,\gamma)^{176\text{m,g}}\text{Lu}$, $^{175}\text{Lu}(n,2n)^{174\text{m,g}}\text{Lu}$, $^{237}\text{Np}(n,2n)^{236\text{m,g}}\text{Np}$,
 $^{241}\text{Am}(n,\gamma)^{242\text{m,g}}\text{Am}$, and $^{243}\text{Am}(n,\gamma)^{244\text{m,g}}\text{Am}$ using modeled

level structures in the deformed, odd-odd product nuclei.

We find:

- 1) that the hundreds of discrete levels and their gamma-ray branching ratios provided by the modeling are necessary to achieve agreement with experiment;
- 2) that many rotational bands must be included in order to obtain a sufficiently representative selection of K quantum numbers;
- 3) that the levels of each band must be extended to appropriately high values of angular momentum.

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All of the cross-section calculations were made with our version of the STAPRE statistical model code,¹ with no fission competition. Appropriate neutron potentials were used for the different targets²⁻⁴ and the Cook-modified, Gilbert-Cameron level density parameters were employed, further adjusted to match discrete level information or to reproduce D_{ob} values where known. Below about 1.5 MeV in each deformed, odd-odd product nucleus, we replaced the level density expression with one of the modeled discrete level sets summarized in Table I.

Modeled level structures described in:
MODELING LEVEL STRUCTURES OF ODD-ODD DEFORMED NUCLEI

R. W. Hoff, J. Kern, R. Piepenbring, and J. Boisson

this Conference, also Ref. 5

Table I Comparison of modeled and experimental level sets

Level-set designation	Energy range (MeV)	Number of levels	Number of rotational bands	Range of quantum nos. K	Range of quantum nos. I
^{174}Lu A	0-1.50	433	82	0-9	0-12
Expt.	0-0.97	57	10	0-7	0-7
^{176}Lu A	0-1.50	291	62	0-9	0-12
B	0-1.04	109	33	0-9	0-11
C	0-0.77	49	15	0-9	0-10
D	0-0.62	27	8	0-8	0-10
Expt.	0-0.99	38	7	0-7	0-10
^{236}Np A	0-1.48	998	94	0-6	0-20
B	0-0.91	453	71	0-6	0-15
C	0-0.36	50	15	0-6	0-11
D	0-0.20	14	5	1-6	0-9
Expt.	0-0.22	5	3	1-6	1-6
^{242}Am A	0-1.50	788	107	0-7	0-13
Expt.	0-1.10	30	9	0-5	0-7
^{244}Am A	0-1.40	769	101	0-8	0-15
Expt.	0-0.78	44	15	0-6	0-6

Sensitivity studies of the computed isomer ratio to the number of discrete

levels describing ^{176}Lu and ^{236}Np were made. In each case, Set A was truncated several times just below a new band head to yield Sets B-D.

Gamma-Ray Cascade Modeling

Within continuum:

The continuum bins are depopulated according to our E1 and M1 strength function systematics, where the E1 strength function has an energy-dependent Breit-Wigner line shape and the M1 strength function is a constant.⁶ (Also see the poster: "Absolute Dipole Gamma-Ray Strength Functions For ^{176}Lu ," D. Gardner, M. Gardner, and R. Hoff)

Among the discrete levels:

No experimental branching ratio information was employed for the depopulation of the discrete levels. The branching ratios were calculated as described in Ref. 5:

- 1) Intraband M1 transitions dominate
- 2) Branching decay occurs for band head levels, $\Delta K = 0, \pm 1$
- 3) M1 and E1 transitions both have E_γ^3 dependence
- 4) M1 transitions are intrinsically faster than E1 transitions, $E1/M1 = 0.167$

The use, among the discrete levels, of the same E1 and M1 strength functions as described for the continuum led to calculated isomer ratios for the $^{175}\text{Lu}(n, \gamma)$ and $^{237}\text{Np}(n, 2n)$ reactions that were no different from those obtained using a constant E1/M1 ratio of 0.167.

The m/g ratios vs E_η that we calculated for the $^{175}\text{Lu}(n,\gamma)$ reaction, compared with values derived from experimental data at about 30 keV.^{7,8} The use of 291 modeled discrete levels for ^{176}Lu (Set A in Table I) yields the lowest calculated band. If only dipole transitions are allowed during the depopulation of the discrete levels, the lower bound of the band is obtained; if E2 transitions from some of the

band heads are allowed to compete, then the upper bound is calculated. The distribution of the K quantum numbers, $P(K)$, for ^{176}Lu level Sets A-D. Although the $P(K)$ of Sets A and B are quite different, each has a sufficiently representative sampling of K values to yield essentially the same isomer ratios.

The E2 transitions from the band heads that were allowed to compete with the dipole transitions during the depopulation of the discrete levels and that led to the upper bounds of the calculated isomer ratios for Sets A-C.

^{236}Pu Formation Is Important In Reactor Shielding

The calculated g/m ratios for the $^{237}\text{Np}(n,2n)$ reaction vs E_n , compared with the 14-MeV measurement.⁹

The distribution of the K quantum numbers, $P(K)$, for ^{236}Np level Sets A-D. Here, as well, Sets C and D do not sample all of the K values, leading to isomer ratios that are too high.

Our calculated cross section for ^{236}Pu production relative to the total $^{237}\text{Np}(n,2n)$ cross section vs E_n compared with the value derived from the measurement of Ref. 9 and compared with the two predictions of Fort.¹⁰

The calculated g/m ratios when the level modeling allows the maximum angular momentum value of the levels (l_{max}) within a rotational band to be 8 compared to when $l_{\text{max}} = 20$. In each case, the modeled level set has 94 rotational bands. The datum point is from Ref. 9.

Our calculated m/g ratios for the $^{241}\text{Am}(n,\gamma)$ and $^{243}\text{Am}(n,\gamma)$ reactions compared with measurements.^{11,12} We also computed isomer ratios for s-wave neutrons leading to the 2^- and 3^- resonances for comparison with the thermal and epithermal data. Other calculational results are shown: from Ref. 11 ——— and from Ref. 12 ———.

The spin distributions among the discrete levels that we calculate after the gamma-ray cascade from the continuum for both the 2^- and 3^- resonance cases. These distributions show why the high spin state is favored by the 3^- resonance and why we obtain the relative order of the isomer ratios for each case.

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