LA-6595-MS
Informal Report
(ENDF-241)

C.3

UC-34c and UC-79

Issued: November 1976

Distribution of Independent Fission-Product Yields to Isomeric States

by

David G. Madland
Talmadge R. England

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87545

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
CONTRACT W-7405-ENG. 36

This work supported by the US Energy Research and Development Administration, Division of Physical Research, contract 9502-E336.

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price: Printed Copy $4.00 Microfiche $3.00

DISTRIBUTION OF INDEPENDENT FISSION-PRODUCT YIELDS TO ISOMERIC STATES

by

David G. Madland and Talmadge R. England

ABSTRACT

A simple one-parameter model is presented for calculating the distribution of independent yield strength between ground and isomeric states of primary fission products formed by neutron-induced fission of actinide nuclei. Yield branching ratios are calculated as a function of neutron energy (thermal, fast, and 14-MeV) for 144 nuclides having isomeric states with $T_{1/2} \geq 0.1$ s. The results are proposed for use in the ENDF/B-V yield files.

I. INTRODUCTION

Nuclear isomeric states are low-lying ($\lesssim$ 1-MeV excitation) metastable states. They occur where the angular momentum differences between the metastable state and all lower states are large and where the corresponding energy differences are small. In these circumstances electromagnetic transition probabilities are strongly reduced because high-order multipoles occur in the reduced matrix elements and limited energy (frequency) is available for the emitted radiation. Equivalently, the lifetimes of the states are long, that is, they are metastable or isomeric. In a shell model picture these states can exist because major shells occupied by particles of high angular momentum are preceded by closely lying (in energy) subshells occupied by particles of low angular momentum,† which reproduces the conditions set forth above.

Isomeric state transitions encompass wide variations in the multipole type and order (M2, E3, M3, E4, M4, ...) and frequency (~1-keV to ~1-MeV) of the emitted γ rays, as well as competing decay modes such as internal conversion and β decay. Consequently, the lifetimes of isomeric states span a wide range: experimental determinations range from $\sim 10^{-6}$ s to $\sim 10^{10}$ s (the lower limit is a matter of definition, therefore arbitrary). Similarly, the nuclear ground states to which the isomeric states must ultimately decay (except in instances of β decay of either the isomeric state or a lower lying intermediate state) display an equally wide range of lifetimes, ~1 s to stability, due to variations (for example) in the controlling factors of β decay, such as end-point energies and interaction matrix elements. A consequence of the wide variation in the observed half-lives of isomeric states and β-unstable ground states is that any detailed description of the time evolution of a collection of excited nuclei must explicitly account for advancements or retardations, relative to ground state lifetimes, due to the population of isomeric states. In the case of a single excited nucleus an isomeric state can be the dominant factor in a nuclear cascade calculation.

The time development of the decay energy release following binary fission is an example in

†Major shell closures at Z,N = 50, 82, and 126 involve $1g_{9/2}$, $1h_{11/2}$, and $1i_{13/2}$ particles, respectively. The adjacent, lower, subshells are occupied by, respectively, $2p_{1/2}$, $2d_{3/2}$, and $3p_{1/2}$ neutrons or $2p_{1/2}$, $3s_{1/2}$, and $3p_{1/2}$ protons.

which the role of the isomeric states is important. Primary fission fragments formed at the scission point undergo prompt neutron and γ emission, the degree depending upon the initial fragment excitation and neutron excess. The resulting primary fission products are either stable (a small fraction) or are unstable to β decay and/or delayed neutron emission (a large fraction). If the existence of isomeric states is invoked, the latter group (large fraction) is split into an unchanged component in which no isomeric states exist and a component consisting of species occupying either their unstable ground state or their metastable isomeric state. The paths and the times that elements of the second component take in order to reach the stability line depend crucially upon the initial populations of the isomeric states relative to those of the ground states. The time development of the energy release of this component is thereby sensitive to the initial relative populations (branching fractions). In the case of thermal fission of actinide nuclei, such as $^{233, 235}$U or $^{239, 241}$Pu, roughly 800 primary products are formed. Approximately 100 of these are stable while ~700 are unstable of which ~150 (~20%) have known isomeric states with half-lives $\tau \geq 0.1$ s.[1]

This report is a summary of a one-parameter model calculation of the relative populations between isomeric states and ground states of primary fission products (independent fission yields) formed in neutron-induced fission. Branching ratios for the distribution of independent yield strengths between these states are calculated for 144 nuclides as a function of neutron energy (thermal, fast, and 14-MeV). In Sec. II the model is developed and simplifying assumptions are stated and discussed. Section III presents the calculation, the empirical determination of the model parameter, and the results. Comparisons to experimental data, a summary, and future work are discussed in Sec. IV.

II. DEVELOPMENT OF THE MODEL

Perhaps the best way to calculate branching ratios for the distribution of independent yield strengths between ground and isomeric states is to perform statistical nuclear cascade calculations. These require quantitative information (or assumptions) concerning initial fragment excitation energies and angular momenta, level density descriptions in both continuum and resolved regions, the most likely multipolarities and corresponding transition probabilities for γ de-excitation, neutron emission probabilities and transferred angular momenta, and spins and parities of the ground and isomeric states. Much of this information is unavailable (at the present time) for fission fragments formed in thermal fission† and even less fission fragment information exists for fast and 14-MeV neutron-induced fission. This fact does not by itself preclude a full cascade calculation approach to the problem because sufficient measurements have been made to provide a basis for reasonable assumptions where data do not exist. However, a full cascade approach for several hundred cases is probably premature at this time because few well-measured yield branching ratios exist by which the calculational assumptions might be unfolded and sensitively tested. Thus, a simplified approach is used in the present work.

A number of isomeric-state/ground-state ratios have been measured and analyzed (using a statistical cascade approach) from the point of view of determining the initial fission fragment angular momentum for reasons pertinent to fundamental fission theory. Our approach is to turn the problem around by simply retaining the dominant features of these calculations, treating the initial fission fragment angular momentum as a parameter, and calculating the branching ratio. An assessment of the fragment angular momentum studies[2-6] and other work[7,8] on isomeric states leads to the following conclusions or assumptions applicable to the present approach:

A.

Calculations of the branching ratios in reactions where the angular momentum distribution of the compound system is known indicate that the relative probability of forming each state is governed mainly by (1) the angular momentum differences between the states participating in the cascade, and (2) the angular momenta of the ground and isomeric states. In short, sums or integrals over the angular momentum density distribution, P(J), are a dominant feature of the calculation. The statistical model[9,10]

†For example, initial fragment excitation energies and neutron emission probabilities are not well known for fission fragments with large neutron excess.

predicts P(J) to be of the form

$$P(J) = P_0(2J+1) \exp\left[-(J+\tfrac{1}{2})^2/\langle J^2\rangle\right] \quad , \qquad (1)$$

where $J_{rms} \equiv \sqrt{\langle J^2\rangle}$ characterizes the angular momentum of the initial fragment.

B.

The calculated branching ratios are relatively insensitive to the number of γ rays assumed in the cascade, N_γ, and the number of emitted neutrons assumed, N_n, as long as they are within reasonable limits (dipole radiation only and prompt neutrons only). For example, in an analysis[2] of the $^{81}Se^m/^{81}Se^g$ ratio, populated in ^{239}Pu thermal fission, the calculated ratio changes by < 10% if N_γ is changed from 3 to 3 ± 1. Similarly, in a study[3] of the $^{134}Cs^m/^{134}Cs^g$ ratio, populated in photofission of ^{233}U with ~16-MeV γ rays, the calculated values of the ratio change by ~4% if N_γ is increased from 2 to 3. In an analysis[4] of the $^{131}Te^m/^{131}Te^g$ ratio, populated in the $^{238}U(\alpha,f)$ reaction at 33 MeV, the calculated ratio changes by < 15% for N_n ranging from 0 to 2 (this work also concluded that the ratio was rather insensitive to N_γ).

C.

The important feature that emerges from these analyses[2-6] is that for the distribution defined by Eq. 1, a correlation exists between the rms averaged fragment spin, J_{rms}, and the isomeric-state/ground-state branching ratio, R. When all approximations and uncertainties are folded in, J_{rms} is determined to within ~1.5 units of angular momentum, that is, to within ~10-25%. Thus, if J_{rms} is specified, R can be calculated to within some level of confidence.

D.

Within the experimental uncertainties in the measurements of R and approximations used in cascade-model calculations of R, the following trends appear to exist:

1. For a given fission fragment species the value of R is roughly independent of the species of the compound (fissioning) system[†] provided the compound systems are at approximately the same excitation energy (formed by particles of similar energy, for example). This statement is accurate to within 30% for the formation of the $^{131}Te^m/^{131}Te^g$ ratio[4] in thermal fission of ^{233}U, ^{235}U, and ^{239}Pu. Similar evidence may be found in Ref. 3 and Ref. 11.

2. For a given fission fragment species formed by fission of a given compound system, R increases with the excitation energy of the compound system (increasing neutron energy, for example) provided the spin of the isomeric state, J_m, is greater than that of the ground state, J_g. That is, J_{rms} increases with the incident particle energy. See, for example, the change in the $^{133}Xe^m/^{133}Xe^g$ ratio with increasing neutron energy in $^{235}U + n$ fission.[11] Note, however, that the $^{135}Xe^m/^{135}Xe^g$ ratio (same reference) does not show this trend. Further supporting evidence may be found in the charged-particle induced-fission data reported in Ref. 4.

3. Different fission fragment species with the same values of J_g and J_m have approximately the same R values provided the respective compound systems are at approximately the same excitation energy (same incident neutron energy, for example). This statement is accurate to within 20-60% for the charged-particle induced-fission data of Ref. 4.

The data assessments summarized by paragraphs A through D allow the following model assumptions for the calculation of isomeric-state/ground-state independent yield branching ratios, R, in neutron induced fission.

MODEL ASSUMPTIONS

It is assumed that

(1) Fission fragments are formed with a density distribution, P(J), of total angular momentum, J, which is parameterized by a characteristic value, $J_{rms} = \sqrt{\langle J^2\rangle}$, as given by Eq. 1.

(2) J_{rms} is constant for all fragment masses in the neutron-induced fission of all actinide systems, but varies with incident neutron energy.

(3) The branching mechanism is, simply, that fragments with J values near that of the isomeric state (J_m) γ decay to the isomeric state, fragments with J values near the ground state, J_g, γ decay to the ground state, and fragments with J values exactly between J_g and J_m divide equally among ground and isomeric states. The

[†]Evidence[2-6,11] can be found to support or oppose a dependence upon the ground-state spin of the target nucleus.

driving force is that electromagnetic transition rates are generally strongest for minimum ΔJ. Neutron emission is ignored.

The branching ratio is obtained from the ratio of two sums over P(J) in which the sum limits satisfy assumption (3). The sums are then replaced by integrals. No multipolarities are assumed for the γ rays and no electromagnetic transition selection rules are invoked. It is assumed that their effects are effectively cancelled out to first order in the integral ratio. The branching ratio, R, is obtained from Eq. 2 if $J_m > J_g$ and from Eq. 3 if $J_m < J_g$. In both equations J_c is chosen to satisfy assumption (3).

$$\frac{IY(m)}{IY(g) + IY(m)} = \frac{\int_{J_c}^{\infty} P(J)\,dJ}{\int_{0 \text{ or } 1/2}^{\infty} P(J)\,dJ} , \qquad (2)$$

$$\frac{IY(g)}{IY(g) + IY(m)} = \frac{\int_{J_c}^{\infty} P(J)\,dJ}{\int_{0 \text{ or } 1/2}^{\infty} P(J)\,dJ} . \qquad (3)$$

In either case, R is defined as IY(m)/IY(g), where IY(m) and IY(g) are the independent yields to the isomeric state and the ground state, respectively.

III. CALCULATION

There are eight separate cases to calculate R in using Eqs. 2 and 3. These differ according to whether the mass number A and/or $|J_m - J_g|$ are even or odd and whether J_m is greater or less than J_g. The cases are easily constructed by assembling hypothetical examples.

Suppose that $J_m > J_g$, so that Eq. 2 is appropriate. If A is even (odd) the lower limit of the integral in the denominator of Eq. 2 is 0 (1/2).† If A is even or odd and $|J_m - J_g|$ is odd, then $J_c = \frac{1}{2}(J_m + J_g) + \frac{1}{2} = \frac{1}{2}(J_m + J_g + 1)$. If, however, A is even or odd and $|J_m - J_g|$ is even, then $J_c = \frac{1}{2}(J_m + J_g) + 1 = \frac{1}{2}(J_m + J_g + 2)$, but there is an additional term in the numerator of Eq. 2 due to dividing the contribution from $J = \frac{1}{2}(J_m + J_g)$ equally between the ground state and the isomeric state. This additional term has the value*

$$\tfrac{1}{2}(J_m + J_g + 1)\ \exp\left[-(J_m + J_g + 1)^2/4\langle J^2\rangle\right] \Delta J ,$$

where $\Delta J = 1$. The above discussion is identically valid for $J_m < J_g$ except that Eq. 3 is used to evaluate R instead of Eq. 2.

Performing the integrations, four functions (F_1, F_2, F_3, F_4) are obtained which are used to evaluate R using either Eq. 2 or Eq. 3. The extracted values of R are summarized in Table I for the eight possible cases. The F functions to be used are given by Eqs. 4-7.

A odd, $|J_m - J_g|$ even

$$F_1 = \exp(1/\langle J^2\rangle)\left\{\exp\left[-(1/\langle J^2\rangle)\left(\frac{J_m+J_g+3}{2}\right)^2\right] + (1/\langle J^2\rangle)\left(\frac{J_m+J_g+1}{2}\right)\exp\left[-(1/\langle J^2\rangle)\left(\frac{J_m+J_g+1}{2}\right)^2\right]\right\} \qquad (4)$$

A odd, $|J_m - J_g|$ odd

$$F_2 = \exp(1/\langle J^2\rangle)\left\{\exp\left[-(1/\langle J^2\rangle)\left(\frac{J_m+J_g+2}{2}\right)^2\right]\right\} , \qquad (5)$$

† If $J_{rms} \gg 1$ the difference in the magnitude of the integral in the denominator for lower limits of 0 and ½ is negligible in light of the approximations used in the model. The distinction is maintained for completeness.

* If $(J_m + J_g)\Delta J/J_{rms}^2 \ll 1$ the additional term is negligible in light of the approximations used in the model. The distinction is maintained for completeness.

A even, $|J_m - J_g|$ even

$$F_3 = \exp\left[-(1/\langle J^2\rangle)\left(\frac{J_m+J_g+2}{2}\right)\left(\frac{J_m+J_g+4}{2}\right)\right]$$

$$+ (1/\langle J^2\rangle)\left(\frac{J_m+J_g+1}{2}\right)\exp\left[-(1/\langle J^2\rangle)\left(\frac{J_m+J_g}{2}\right)\left(\frac{J_m+J_g+2}{2}\right)\right] \quad , \qquad (6)$$

A even, $|J_m - J_g|$ odd

$$F_4 = \exp\left[-(1/\langle J^2\rangle)\left(\frac{J_m+J_g+1}{2}\right)\left(\frac{J_m+J_g+3}{2}\right)\right] . \qquad (7)$$

Use of Eqs. 4-7 and Table I are illustrated by the following two examples: (1) Suppose A is odd, $J_m = 13/2$ and $J_g = 3/2$. Then states with $J \geq 9/2$ presumably decay to the isomeric state and states with $J \leq 7/2$ presumably decay to the ground state. Since $J_m > J_g$, Eq. 2 is appropriate, and since A is odd, the lower limit of the integral in the denominator is 1/2. Because $|J_m - J_g| = 5$ is odd, the lower limit of the integral in the numerator, J_c, is given by $J_c = \frac{1}{2}(J_m + J_g + 1) = 9/2$. Thus, one obtains the function F_2 by evaluating Eq. 2. The expression for R is then given by Formula 3 of Table I. (2) Suppose A is even, $J_m = 2$ and $J_g = 8$. Then states with $J \geq 6$ presumably decay to the ground state, states with $J \leq 4$ presumably decay to the isomeric state, and states with $J = 5$ divide equally between the ground and isomeric states. Since $J_m < J_g$, Eq. 3 is appropriate and since A is even, the lower limit of the integral in the denominator is 0. Because $|J_m - J_g| = 6$ is even, the lower limit of the integral in the numerator is given by $J_c = \frac{1}{2}(J_m + J_g + 2) = 6$. Thus, one obtains the function F_3 by evaluating Eq. 3. The expression for R is then given by Formula 6 of Table I.

It remains to specify the rms value, J_{rms}, of the initial fragment angular momentum as a function of neutron energy. As a starting point we have used values determined in the statistical cascade analyses discussed in the beginning of Sec. II: a study of the $^{83}Se^m/^{83}Se^g$ ratio,[2] populated in ^{239}Pu thermal fission, resulted in $J_{rms} \sim 8$ units; analysis of the $^{131}Te^m/^{131}Te^g$ and $^{133}Te^m/^{133}Te^g$ ratios,[4] populated in ^{235}U thermal fission, resulted in J_{rms} values of 6.0 ± 1.5 and 5.9 ± 1.5 units, respectively.

It is therefore assumed that $5 < J_{rms} < 8$ for thermal-neutron-induced fission. Using Wolfsberg's compilation[11] of experimental results, all possible isomeric-state/ground-state ratios based upon experimental data alone were listed in order to find the maximum number of cases wherein J_m, J_g, and En(incident neutron energy) are fixed at one set of values. Ten cases were found in which the neutron energy is thermal, $J_m = 11/2$, and $J_g = 3/2$ (the cases span $^{233,235}U$, ^{239}Pu thermal fission and R ratios for $^{131,133}Te$ and $^{133,135}Xe$). The model would predict the same R value for each case and, indeed, the experimental points give R = 2.322 ± 0.323. Using this R ± ΔR value in Formula 1 of Table I yields $J_{rms} = 7.5 \pm 0.5$ for thermal fission. Adopting this value, the J_{rms} value for fast and 14-MeV neutron-induced fission must have $J_{rms} > 7.5 \pm 0.5$ based on the discussion in Sec. II-D-2. Again, use of the data compiled in Ref. 11 together with a data point for 10-MeV proton-induced fission in Ref. 5 indicates that $J_{rms} \simeq 8$ for fast neutrons ($E_n \lesssim$ 2-MeV), $J_{rms} \simeq 9$ for 10-MeV protons (neutrons), and $J_{rms} \simeq 10$ for 14-MeV neutrons. Uncertainties of these values are difficult to estimate because of sparse data, but $\Delta J_{rms} = \pm$ 1-2 units is probably not unreasonable.[12]

A plot of J_{rms} vs E_n indicates $J_{rms} \propto \sqrt{E_n}$. This behavior can be reproduced by adding the thermal J_{rms} value (7.5) in quadrature with kR of the incoming neutron of energy E_n, where k is the wave number and R is the target radius. This presumption yields J_{rms} = (7.5, 7.6, 7.8, 9.1, 9.7) for E_n (MeV) = (0.0, 0.5, 2.0, 10.0, 14.0) which agrees well with the

TABLE I

ISOMERIC STATE TO GROUND STATE INDEPENDENT YIELD BRANCHING RATIO, R

ODD A

1 $J_m - J_g$ = even integer $J_m > J_g$ $\left(\frac{F_1}{1 - F_1}\right)$	2 $J_m - J_g$ = even integer $J_m < J_g$ $\left(\frac{1 - F_1}{F_1}\right)$
3 $J_m - J_g$ = odd integer $J_m > J_g$ $\left(\frac{F_2}{1 - F_2}\right)$	4 $J_m - J_g$ = odd integer $J_m < J_g$ $\left(\frac{1 - F_2}{F_2}\right)$

EVEN A

5 $J_m - J_g$ = even integer $J_m > J_g$ $\left(\frac{F_3}{1 - F_3}\right)$	6 $J_m - J_g$ = even integer $J_m < J_g$ $\left(\frac{1 - F_3}{F_3}\right)$
7 $J_m - J_g$ = odd integer $J_m > J_g$ $\left(\frac{F_4}{1 - F_4}\right)$	8 $J_m - J_g$ = odd integer $J_m < J_g$ $\left(\frac{1 - F_4}{F_4}\right)$

above. In summary, the present calculation uses J_{rms} = (7.5, 7.5, 8.0, 9.0, 10.0) for E_n (MeV) = (0.0, 0.5, 2.0, 10.0, 14.0).

The calculated isomeric-state to ground-state independent yield ratios, R, are presented in Table II together with experimental results whenever they exist. The table is self-explanatory with the following exceptions: (1) column 2 contains "G," "M" for ground and isomeric states and "Ex" for excitation energy, in keV, relative to the ground state, (2) column 5 contains a reference for the information in the previous four columns and the appropriate formula number from Table I, (3) an R value with parentheses means that some quantity (usually J) used in the calculation is not known with certainty, and (4) all references in Table II are compiled at the end of the table.

IV. SUMMARY

Comparisons of calculated and experimental R values are shown in Figs. 1 and 2. In Fig. 1 the data points for $^{131,133}Te$ and $^{133,135}Xe$ were used in the determination of J_{rms} for the thermal neutrons. However, model tests are provided by the remaining six data points of the figure. The

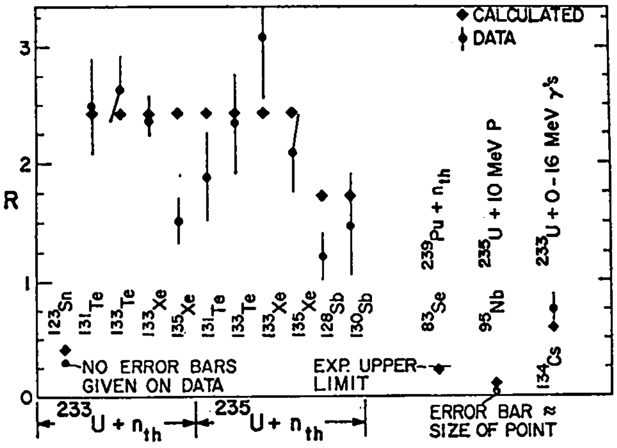

Fig. 1. Comparisons of calculated and experimental isomeric-state/ground-state independent yield ratios.

agreement is quite good in five of the six cases and if uncertainties in J_{rms} are folded into the calculated values (15-30%) agreement exists in every case. It is worthwhile pointing out that calculation of the R values for $^{128,130}Sb$ by the statistical weighting factor $(2J_m + 1)/(2J_g + 1)$, as suggested by Holmholz and Segre,[13] underpredicts the data by a factor ~2 whereas the present work gives values slightly higher than the data. The data of Fig. 2 were used in determining J_{rms} as a function of E_n, thus no model test is provided. Note that the range of the calculated values due to uncertainties in J_{rms} has not been indicated in the figure. The figure is presented to illustrate the energy dependence of J_{rms} for the calculations given in Table II.

The next attempt to catalog unknown isomeric-state/ground-state independent yield branching ratios as a function of E_n should probably be a series of full statistical nuclear cascade calculations, especially if more detailed and accurate data become available over the short term. In lieu of this, however, the present model could perhaps be improved by making use of the fact that J_{rms} for light fragments (A < 118, for example) is apparently less than J_{rms} for heavy fragments, all other quantities fixed.[14] More work could also be done on the question of the influence of the ground state spin of the target nucleus, that is, the angular momentum distribution of the initial compound system should be studied. Finally, the influence of states lying between ground and isomeric states should be examined

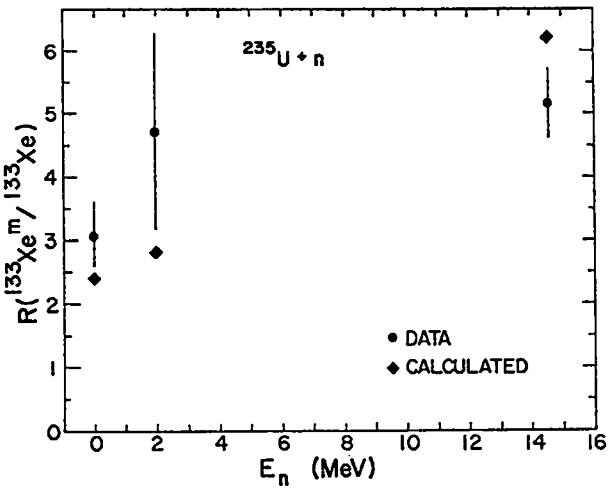

Fig. 2. Comparison of calculated and experimental isomeric-state/ground-state independent yield ratio as a function of E_n for ^{133}Xe in ^{235}U fission.

more closely.

V. ACKNOWLEDGMENT

We wish to thank George P. Ford for helpful discussions and for pointing out the "2J + 1 weighting rule" suggested by Helmholz and Segre.

REFERENCES

1. T. R. England and R. E. Schenter, "ENDF/B-IV Fission-Product Files: Summary of Major Nuclide Data" Los Alamos Scientific Laboratory report LA-6116-MS (October 1975).

2. I. F. Croall and H. H. Willis, "The Yields of the Isomers of ^{81}Se and ^{83}Se in the Thermal Neutron Fission of ^{239}Pu," J. Inorg. Nucl. Chem. 25, 1213 (1963).

3. H. Warhanek and R. Vandenbosch, "Relative Cross-Sections for Formation of the Shielded Isomeric Pair ^{134m}Cs and ^{134}Cs in Medium Energy Fission," J. Inorg. Nucl. Chem. 26, 669 (1964).

4. D. G. Sarantites, G. E. Gordan, and C. D. Coryell, "Ratios of Independent Yields of the Isomers $Te^{131-131m}$ and $Te^{133-133m}$ in Fission," Phys. Rev. 138, B353 (1965).

5. C. Rudy, R. Vandenbosch, and C. T. Radcliffe, "Relative Independent Yields for ^{95}Nb and ^{95m}Nb from Low Energy Fission," J. Inorg. Nucl. Chem. 30, 365 (1968).

6. W. D. Loveland and Y. S. Shum, "Fission-Fragment Angular Momentum in Charged-Particle-Induced Fission I. ^{134}Cs and 115Cd Isomer Ratios," Phys. Rev. C4, 2282 (1971).

7. J. R. Huizenga and R. Vandenbosch, "Interpretation of Isomeric Cross-Section Ratios for (n,γ) and (γ,n) Reactions," Phys. Rev. 120, 1305 (1960).

8. R. Vandenbosch and J. R. Huizenga, "Isomeric Cross-Section Ratio for Reactions Producing the Isomeric Pair $Hg^{197,197m}$," Phys. Rev. 120, 1313 (1960).

9. H. A. Bethe, "Nuclear Physics B. Nuclear Dynamics, Theoretical," Revs. Mod. Phys. 9, 84 (1937).

10. C. Bloch, "Thory of Nuclear Level Density," Phys. Rev. 93, 1094 (1954).

11. Kurt Wolfsberg, "Estimated Values of Fractional Yields from Low Energy Fission and a Compilation of Measured Fractional Yields," Los Alamos Scientific Laboratory report LA-5553-MS (May 1974).

12. Robert Vandenbosch and John R. Huizenga, Nuclear Fission (Academic Press, N.Y., 1973) p. 369.

13. E. Segre and A. C. Helmholz, "Nuclear Isomerism," Revs. Mod. Phys. 21, 271 (1949).

14. J. B. Wilhelmy, E. Cheifetz, R. C. Jared, S. G. Thompson, and H. R. Bowman, "Angular Momentum of Primary Products Formed in the Spontaneous Fission of ^{252}Cf," Phys. Rev. C5, 2041 (1972).

TABLE II

*** ISOMERIC STATE TO GROUND STATE INDEPENDENT YIELD RATIOS ***

NUCLEUS	STATE,EX	T(1/2)	J,P	REF,FOR	0.0-0.5MEV,JRMS=7.5 R(CAL)	0.0-0.5MEV,JRMS=7.5 R(EXP),REF	2.0MEV,JRMS=8.0 R(CAL)	2.0MEV,JRMS=8.0 R(EXP),REF	14.0MEV,JRMS=10.0 R(CAL)	14.0MEV,JRMS=10.0 R(EXP),REF
30ZN69	G 000.0	58. M	1/2 -	1, 1						
30ZN69	M 438.7	13.9 M	(9/2) +	1, 1	(4.325)		(4.968)		(7.961)	
30ZN71	G 000.0	2.4 M	1/2 -	1, 1						
30ZN71	M 157.0	3.92 H	(9/2) +	1, 1	(4.325)		(4.968)		(7.961)	
32GE73	G 000.0	STABLE	9/2 +	1, 2						
32GE73	M 66.8	0.53 S	(1/2)(-)	1, 2	(0.231)		(0.201)		(0.126)	
34SE73	G 000.0	7.1 H	(9/2)(+)	1, 2						
34SE73	M 190.	42. M	(1/2)(-)	1, 2	(0.231)		(0.201)		(0.126)	
33AS74	G 000.0	17.7 D	2 -	1, 7						
33AS74	M 283.0	8.0 S	(5)	1, 7	(2.342)		(2.726)		(4.517)	
32GE75	G 000.0	83. M	(1/2)(-)	1, 3						
32GE75	M 139.0	46. S	(7/2)(+)	1, 3	(6.543)		(7.510)		(12.007)	
32GE77	G 000.0	11.3 H	(7/2)(+)	1, 4						
32GE77	M 159.7	54. S	(1/2)(-)	1, 4	(0.153)		(0.133)		(0.083)	
34SE77	G 000.0	STABLE	1/2 -	1, 3						
34SE77	M 161.9	17.5 S	7/2 +	1, 3	6.543		7.510		12.007	

TABLE II (continued)

*** ISOMERIC STATE TO GROUND STATE INDEPENDENT YIELD RATIOS ***

NUCLEUS	STATE,EX	T(1/2)	J,P	REF,FOR	0.0-0.5MEV,JRMS=7.5 R(CAL)	R(EXP),REF	2.0MEV,JRMS=8.0 R(CAL)	R(EXP),REF	14.0MEV,JRMS=10.0 R(CAL)	R(EXP),REF
35BR77	G 000.0	56. H	3/2 -	1, 3						
35BR77	M 106.2	4.28 M	9/2 +	1, 3	3.272		3.786		6.179	
34SE79	G 000.0	6.5E4Y	7/2 +	1, 4						
34SE79	M 96.0	3.9 M	1/2 -	1, 4	0.153		0.133		0.083	
35BR79	G 000.0	STABLE	3/2 -	1, 3						
35BR79	M 208.	4.8 S	9/2 +	1, 3	3.272		3.786		6.179	
36KR79	G 000.0	34.9 H	(1/2)(-)	1, 3						
36KR79	M 127.0	55. S	(7/2)(+)	1, 3	(6.543)		(7.510)		(12.007)	
35BR80	G 000.0	17.6 M	1 +	1, 5						
35BR80	M 85.0	4.4 H	5 -	1, 5	3.017		3.483		5.657	
34SE81	G 000.0	18. M	(1/2)(-)	1, 3						
34SE81	M 103.0	57. M	(7/2)(+)	1, 3	(6.543)		(7.510)		(12.007)	
36KR81	G 000.0	2.1E5Y	7/2 +	1, 4						
36KR81	M 190.0	13. S	1/2 -	1, 4	0.153		0.133		0.083	
37RB81	G 000.0	4.7 H	3/2 -	1, 3						
37RB81	M 85.0	32. M	9/2 +	1, 3	3.272		3.786		6.179	

TABLE II (continued)

*** ISOMERIC STATE TO GROUND STATE INDEPENDENT YIELD RATIOS ***

					0.0-0.5MEV,JRMS=7.5		2.0MEV,JRMS=8.0		14.0MEV,JRMS=10.0	
NUCLEUS	STATE,EX	T(1/2)	J,P	REF,FOR	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF
35BR82	G 000.0	35.5 H	5 -	1, 8						
35BR82	M 46.0	6.1 M	2 -	1, 8	0.427		0.367		0.221	
37RB82	G 000.0	1.3 M	1 +	1, 5						
37RB82	M 300.	6.4 H	5 -	1, 5	3.017		3.483		5.657	
34SE83	G 000.0	23. M	(9/2) +	1, 2						
34SE83	M 220.0	69. S	(1/2) -	1, 2	(0.231)	L0.25, 6	(0.201)		(0.126)	
36KR83	G 000.0	STABLE	9/2 +	1, 2						
36KR83	M 41.0	1.9 H	1/2 (-)	1, 2	0.231		0.201		0.126	
37RB84	G 000.0	33. D	2 -	1, 5						
37RB84	M 463.6	20.5 M	6 +	1, 5	1.799		2.098		3.498	
39Y 84	G 000.0	40. M	(4) (-)	2, 8						
39Y 84	M	4.6 S	(1) (+)	2, 8	(0.238)		(0.206)		(0.127)	
36KR85	G 000.0	10.73Y	9/2 +	1, 2						
36KR85	M 305.0	4.36 H	1/2 -	1, 2	0.231		0.201		0.126	
38SR85	G 000.0	65.19D	(9/2) +	1, 2						
38SR85	M 238.6	69.5 M	(1/2) -	1, 2	(0.231)		(0.201)		(0.126)	

TABLE II (continued)

*** ISOMERIC STATE TO GROUND STATE INDEPENDENT YIELD RATIOS ***

					0.0-0.5MEV,JRMS=7.5		2.0MEV,JRMS=8.0		14.0MEV,JRMS=10.0	
NUCLEUS	STATE,EX	T(1/2)	J,P	REF,FOR	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF
39Y 85	G 000.0	4.8 H	(9/2)(+)	1, 2						
39Y 85	M 40.	2.68 H	(1/2)(-)	1, 2	(0.231)		(0.201)		(0.126)	
40ZR85	G 000.0	7.92 M	(7/2)(+)	2, 4						
40ZR85	M 292.2	10.9 S	(1/2)(-)	2, 4	(0.153)		(0.133)		(0.083)	
37RB86	G 000.0	18.66D	2 -	1, 5						
37RB86	M 555.9	1.017M	(6) -	1, 5	(1.799)		(2.098)		(3.498)	
39Y 86	G 000.0	14.6 H	4 -	1, 5						
39Y 86	M 218.2	48. M	(8) (+)	1, 5	(0.737)		(0.885)		(1.590)	
38SR87	G 000.0	STABLE	9/2 +	1, 2						
38SR87	M 388.4	2.806H	1/2 -	1, 2	0.231		0.201		0.126	
39Y 87	G 000.0	80.3 H	1/2 -	1, 1						
39Y 87	M 381.3	12.7 H	9/2 +	1, 1	4.325		4.968		7.961	
39Y 89	G 000.0	STABLE	1/2 -	1, 1						
39Y 89	M 909.1	16.06S	9/2 +	1, 1	4.325		4.968		7.961	
40ZR89	G 000.0	78.43H	9/2 +	1, 2						
40ZR89	M 587.8	4.18 M	1/2 -	1, 2	0.231		0.201		0.126	

TABLE II (continued)

*** ISOMERIC STATE TO GROUND STATE INDEPENDENT YIELD RATIOS ***

					0.0-0.5MEV,JRMS=7.5		2.0MEV,JRMS=8.0		14.0MEV,JRMS=10.0	
NUCLEUS	STATE,EX	T(1/2)	J,P	REF,FOR	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF
41NB89	G 000.0	2.03 H	(9/2)(+)	1, 2						
41NB89	M 70.	42. M	(1/2)(-)	1, 2	(0.231)		(0.201)		(0.126)	
37RB90	G 000.0	154. S	(1) (-)	1, 7						
37RB90	M 121.5	256. S	(4) (-)	1, 7	(4.205)		(4.849)		(7.843)	
39Y 90	G 000.0	64.1 H	2 -	1, 7						
39Y 90	M 680.	3.19 H	7 +	1, 7	1.419		1.672		2.858	
40ZR90	G 000.0	STABLE	0 +	1, 7						
40ZR90	M 2319.	0.83 S	5 -	1, 7	4.205		4.849		7.843	
41NB90	G 000.0	14.59H	8 +	1, 6						
41NB90	M 124.8	18.8 S	4 -	1, 6	1.357		1.130		0.629	
39Y 91	G 000.0	58.51D	1/2 -	1, 1						
39Y 91	M 555.6	49.71M	9/2 +	1, 1	4.325		4.968		7.961	
41NB91	G 000.0	1.E4 Y	9/2 +	1, 2						
41NB91	M 104.5	62. D	1/2 -	1, 2	0.231		0.201		0.126	
42MO91	G 000.0	15.49M	9/2 +	1, 2						
42MO91	M 652.9	65.5 S	1/2 -	1, 2	0.231		0.201		0.126	

TABLE II (continued)

*** ISOMERIC STATE TO GROUND STATE INDEPENDENT YIELD RATIOS ***

NUCLEUS	STATE,EX	T(1/2)	J,P	REF,FOR	0.0-0.5MEV,JRMS=7.5 R(CAL)	0.0-0.5MEV,JRMS=7.5 R(EXP),REF	2.0MEV,JRMS=8.0 R(CAL)	2.0MEV,JRMS=8.0 R(EXP),REF	14.0MEV,JRMS=10.0 R(CAL)	14.0MEV,JRMS=10.0 R(EXP),REF
41NB92	G 000.0	1.2E8Y	(7) +	1, 8						
41NB92	M 136.	10.15D	(2) +	1, 8	(0.705)		(0.598)		(0.350)	
41NB93	G 000.0	STABLE	9/2 +	1, 2						
41NB93	M 30.4	13.6 Y	1/2 -	1, 2	0.231		0.201		0.126	
42MO93	G 000.0	3.5E3Y	5/2 +	1, 1						
42MO93	M 242.5	6.85 H	(21/2) +	1, 1	(0.611)		(0.740)		(1.358)	
43TC93	G 000.0	2.75 H	9/2 +	1, 2						
43TC93	M 390.	43.5 M	1/2 -	1, 2	0.231		0.201		0.126	
41NB94	G 000.0	2.0E4Y	6 +	1, 8						
41NB94	M 41.0	6.26 M	3 +	1, 8	0.705		0.598		0.350	
43TC94	G 000.0	293. M	(7) +	1, 8						
43TC94	M 73.	52. M	(2) +	1, 8	(0.705)		(0.598)		(0.350)	
41NB95	G 000.0	35.15D	(9/2) +	1, 2						
41NB95	M 234.7	86.6 H	(1/2) -	1, 2	(0.231)		(0.201)		(0.126)	
43TC95	G 000.0	20.0 H	(9/2) +	1, 2						
43TC95	M 38.9	61. D	(1/2) -	1, 2	(0.231)		(0.201)		(0.126)	

TABLE II (continued)

*** ISOMERIC STATE TO GROUND STATE INDEPENDENT YIELD RATIOS ***

					0.0-0.5MEV,JRMS=7.5		2.0MEV,JRMS=8.0		14.0MEV,JRMS=10.0	
NUCLEUS	STATE,EX	T(1/2)	J,P	REF,FOR	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF
43TC96	G 000.0	4.28 D	7 +	1, 8						
43TC96	M 34.4	51.5 M	4 +	1, 8	1.110		0.928		0.522	
41NB97	G 000.0	72.1 M	(9/2) +	1, 2						
41NB97	M 743.4	60. S	(1/2) -	1, 2	(0.231)		(0.201)		(0.126)	
43TC97	G 000.0	2.6E6Y	(9/2) +	1, 2						
43TC97	M 96.5	87. D	(1/2) -	1, 2	(0.231)		(0.201)		(0.126)	
43TC99	G 000.0	2.1E5Y	9/2 +	3, 2						
43TC99	M 142.	6. H	1/2 -	3, 2	0.231		0.201		0.126	
45RH99	G 000.0	16.1 D	(1/2)(-)	1, 1						
45RH99	M 50.	4.7 H	(9/2)(+)	1, 1	(4.325)		(4.968)		(7.961)	
45RH101	G 000.0	3.3 Y	(1/2)(-)	1, 1						
45RH101	M 157.3	4.34 D	(9/2)(+)	1, 1	(4.325)		(4.968)		(7.961)	
45RH103	G 000.0	STABLE	1/2 -	1, 3						
45RH103	M 40.0	57. M	7/2 +	1, 3	6.543		7.510		12.007	
47AG103	G 000.0	66. M	7/2 +	3, 4						
47AG103	M 138.	5.7 S	(1/2)(-)	3, 4	(0.153)		(0.133)		(0.083)	

TABLE II (continued)

*** ISOMERIC STATE TO GROUND STATE INDEPENDENT YIELD RATIOS ***

					0.0-0.5MEV,JRMS=7.5		2.0MEV,JRMS=8.0		14.0MEV,JRMS=10.0	
NUCLEUS	STATE,EX	T(1/2)	J,P	REF,FOR	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF
45RH104	G 000.0	43. S	1 +	3, 5						
45RH104	M 129.0	4.41 M	5 +	3, 5	3.017		3.483		5.657	
47AG104	G 000.0	67. M	5 (+)	1, 8						
47AG104	M 20.	29. M	2 +	1, 8	0.427		0.367		0.221	
45RH105	G 000.0	36. H	(7/2) +	1, 4						
45RH105	M 129.	30. S	(1/2)(-)	1, 4	(0.153)		(0.133)		(0.083)	
47AG105	G 000.0	40. D	1/2 -	1, 3						
47AG105	M 25.5	7.23 M	7/2 +	7, 3	6.543		7.510		12.007	
47AG106	G 000.0	24. M	1 +	1, 7						
47AG106	M 300.	8.3 D	6 +	1, 7	2.342		2.726		4.517	
46PD107	G 000.0	6.5E6Y	5/2 +	1, 3						
46PD107	M 214.	21.3 S	11/2 -	1, 3	1.879		2.198		3.687	
47AG107	G 000.0	STABLE	1/2 -	1, 3						
47AG107	M 93.1	44.3 S	7/2 +	1, 3	6.543		7.510		12.007	
47AG108	G 000.0	2.41 M	1 +	1, 7						
47AG108	M 109.4	127. Y	(6) +	1, 7	(2.342)		(2.726)		(4.517)	

TABLE II (continued)

*** ISOMERIC STATE TO GROUND STATE INDEPENDENT YIELD RATIOS ***

					0.0-0.5MEV,JRMS=7.5		2.0MEV,JRMS=8.0		14.0MEV,JRMS=10.0	
NUCLEUS	STATE,EX	T(1/2)	J,P	REF,FOR	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF
46PD109	G 000.0	13.46H	5/2 +	1, 3						
46PD109	M 188.9	4.69 M	11/2 -	1, 3	1.879		2.198		3.687	
47AG109	G 000.0	STABLE	1/2 -	1, 3						
47AG109	M 88.0	39.6 S	7/2 +	1, 3	6.543		7.510		12.007	
49IN109	G 000.0	4.2 M	9/2 +	1, 2						
49IN109	M 649.5	1.34 M	1/2 -	1, 2	0.231		0.201		0.126	
47AG110	G 000.0	24.57S	1 +	1, 7						
47AG110	M 117.7	250.4D	6 +	1, 7	2.342		2.726		4.517	
46PD111	G 000.0	22. M	(5/2)(+)	1, 3						
46PD111	M 172.	5.5 M	(11/2)(-)	1, 3	(1.879)		(2.198)		(3.687)	
47AG111	G 000.0	7.47 D	1/2 -	1, 3						
47AG111	M 59.8	74. S	(7/2)(+)	1, 3	(6.543)		(7.510)		(12.007)	
48CD111	G 000.0	STABLE	1/2 +	1, 3						
48CD111	M 396.0	48.7 M	11/2 -	1, 3	3.272		3.786		6.179	
49IN111	G 000.0	2.83 D	9/2 +	1, 2						
49IN111	M 536.3	7.7 M	(1/2) -	1, 2	(0.231)		(0.201)		(0.126)	

TABLE II (continued)

*** ISOMERIC STATE TO GROUND STATE INDEPENDENT YIELD RATIOS ***

					0.0-0.5MEV,JRMS=7.5		2.0MEV,JRMS=8.0		14.0MEV,JRMS=10.0	
NUCLEUS	STATE,EX	T(1/2)	J,P	REF,FOR	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF
49IN112	G 000.0	14.4 M	1 +	1, 7						
49IN112	M 155.	20.9 M	4 +	1, 7	4.205		4.849		7.843	
47AG113	G 000.0	5.37 M	1/2 (-)	1, 3						
47AG113	M	1.2 M	(7/2)(+)	1, 3	(6.543)		(7.510)		(12.007)	
48CD113	G 000.0	93E15Y	1/2 +	1, 3						
48CD113	M 263.7	13.6 Y	11/2 -	1, 3	3.272		3.786		6.179	
49IN113	G 000.0	STABLE	9/2 +	1, 2						
49IN113	M 391.7	99.4 M	1/2 -	1, 2	0.231		0.201		0.126	
50SN113	G 000.0	115.2D	1/2 +	1, 3						
50SN113	M 79.3	20. M	7/2 +	1, 3	6.543		7.510		12.007	
48CD115	G 000.0	2.3 D	(1/2)(+)	1, 3						
48CD115	M 180.	43. D	(11/2)(-)	1, 3	(3.272)		(3.786)		(6.179)	
49IN115	G 000.0	6.E14Y	9/2 +	1, 2						
49IN115	M 335.	4.5 M	1/2 -	1, 2	0.231		0.201		0.126	
48CD117	G 000.0	2.4 H	1/2 +	3, 3						
48CD117	M (133)	3.4 H	11/2 -	3, 3	3.272		3.786		6.179	

TABLE II (continued)

*** ISOMERIC STATE TO GROUND STATE INDEPENDENT YIELD RATIOS ***

					0.0-0.5MEV,JRMS=7.5		2.0MEV,JRMS=8.0		14.0MEV,JRMS=10.0	
NUCLEUS	STATE,EX	T(1/2)	J,P	REF,FOR	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF
49IN117	G 000.0	44. M	9/2 +	3, 2						
49IN117	M 314.	1.93 M	1/2 -	3, 2	0.231		0.201		0.126	
50SN117	G 000.0	STABLE	1/2 +	3, 3						
50SN117	M 317.	14.0 D	11/2 -	3, 3	3.272		3.786		6.179	
51SB118	G 000.0	3.5 M	1 +	3, 7						
51SB118	M 190.	5.1 H	(8) -	3, 7	(1.419)		(1.672)		(2.858)	
49IN119	G 000.0	2.1 M	(9/2)(+)	3, 2						
49IN119	M 300.	18. M	(1/2)(-)	3, 2	(0.231)		(0.201)		(0.126)	
50SN119	G 000.0	STABLE	1/2 +	3, 3						
50SN119	M 89.	245. D	11/2 -	3, 3	3.272		3.786		6.179	
52TE119	G 000.0	15.9 H	(1/2)(+)	1, 3						
52TE119	M 300.	4.7 D	(11/2)(-)	1, 3	(3.272)		(3.786)		(6.179)	
49IN121	G 000.0	30. S	9/2 +	1, 2						
49IN121	M 325.	3.1 M	(1/2) -	1, 2	(0.231)		(0.201)		(0.126)	
50SN121	G 000.0	27.06H	3/2 +	1, 1						
50SN121	M 8.0	76. Y	(11/2) -	1, 1	(2.415)		(2.798)		(4.588)	

TABLE II (continued)

*** ISOMERIC STATE TO GROUND STATE INDEPENDENT YIELD RATIOS ***

					0.0-0.5MEV,JRMS=7.5		2.0MEV,JRMS=8.0		14.0MEV,JRMS=10.0	
NUCLEUS	STATE,EX	T(1/2)	J,P	REF,FOR	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF
52TE121	G 000.0	17. D	1/2 (+)	1, 3						
52TE121	M 294.0	154. D	11/2 (-)	1, 3	3.272		3.786		6.179	
51SB122	G 000.0	2.7 D	2 -	1, 5						
51SB122	M 163.	4.2 M	(8) (-)	1, 5	(1.134)		(1.340)		(2.309)	
49IN123	G 000.0	(6.0S)	(9/2) +	1, 2						
49IN123	M 320.	47.8 S	(1/2) -	1, 2	(0.231)		(0.201)		(0.126)	
50SN123	G 000.0	129.2D	(11/2) -	1, 2						
50SN123	M 24.0	40.08M	(3/2) +	1, 2	(0.414)		(0.357)		(0.218)	
52TE123	G 000.0	1E13 Y	1/2 +	1, 3						
52TE123	M 247.5	119.7D	11/2 -	1, 3	3.272		3.786		6.179	
50SN125	G 000.0	9.64 D	11/2 -	1, 2						
50SN125	M 26.0	9.52 M	(3/2) +	1, 2	(0.414)		(0.357)		(0.218)	
52TE125	G 000.0	STABLE	1/2 +	1, 3						
52TE125	M 144.7	58. D	11/2 -	1, 3	3.272		3.786		6.179	
54XE125	G 000.0	17.0 H	(1/2) +	1, 1						
54XE125	M 252.	57. S	(9/2)(-)	1, 1	(4.325)		(4.968)		(7.961)	

TABLE II (continued)

*** ISOMERIC STATE TO GROUND STATE INDEPENDENT YIELD RATIOS ***

					0.0-0.5MEV,JRMS=7.5		2.0MEV,JRMS=8.0		14.0MEV,JRMS=10.0	
NUCLEUS	STATE,EX	T(1/2)	J,P	REF,FOR	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF
51SB126	G 000.0	12.4 D	8 -	4, 8						
51SB126	M 17.7	19.0 M	5 +	4, 8	1.706		1.399		0.751	
50SN127	G 000.0	2.10 H	(11/2)(-)	1, 2						
50SN127	M	4.4 M	(3/2)(+)	1, 2	(0.414)		(0.357)		(0.218)	
52TE127	G 000.0	9.35 H	3/2 +	1, 1						
52TE127	M 88.3	109. D	11/2 -	1, 1	2.415		2.798		4.588	
54XE127	G 000.0	36.41D	(1/2)(+)	1, 1						
54XE127	M 297.1	70. S	(9/2)(-)	1, 1	(4.325)		(4.968)		(7.961)	
51SB128	G 000.0	9.01 H	8 -	4, 8						
51SB128	M	10.4 M	5 +	4, 8	1.706	1.19, 10	1.399		0.751	
52TE129	G 000.0	69.6 M	3/2 +	1, 1						
52TE129	M 105.5	33.6 D	11/2 -	1, 1	2.415		2.798		4.588	
54XE129	G 000.0	STABLE	1/2 +	1, 3						
54XE129	M 236.1	8.0 D	11/2 -	1, 3	3.272		3.786		6.179	
56BA129	G 000.0	2.2 H	1/2 +	1, 3						
56BA129	M 277.1	2.13 H	(11/2) -	1, 3	(3.272)		(3.786)		(6.179)	

TABLE II (continued)

*** ISOMERIC STATE TO GROUND STATE INDEPENDENT YIELD RATIOS ***

NUCLEUS	STATE,EX	T(1/2)	J,P	REF,FOR	0.0-0.5MEV,JRMS=7.5 R(CAL)	R(EXP),REF	2.0MEV,JRMS=8.0 R(CAL)	R(EXP),REF	14.0MEV,JRMS=10.0 R(CAL)	R(EXP),REF
50SN130	G 000.0	(3.7M)	0 +	17, 7						
50SN130	M	(1.7M)	7 -	17, 7	(2.342)		(2.726)		(4.517)	
51SB130	G 000.0	(33.M)	(8) (-)	4, 8						
51SB130	M	(7.1M)	(5) (+)	4, 8	(1.706)	1.46, 11	(1.399)		(0.751)	
53I 130	G 000.0	(12.H)	5 +	17, 8						
53I 130	M	(9.2M)	2 +	17, 8	(0.427)		(0.367)		(0.221)	
52TE131	G 000.0	25. M	(3/2)(+)	1, 1						
52TE131	M 181.7	1.2 D	(11/2)(-)	1, 1	(2.415)	1.99, 8	(2.798)		(4.588)	
54XE131	G 000.0	STABLE	3/2 +	1, 1						
54XE131	M 163.9	12. D	11/2 -	1, 1	2.415		2.798		4.588	
52TE133	G 000.0	12.5 M	(3/2)(+)	1, 1						
52TE133	M 334.0	53. M	(11/2)(-)	1, 1	(2.415)	2.43, 9	(2.798)		(4.588)	
53I 133	G 000.0	20.9 H	7/2 +	17, 1						
53I 133	M 1634.2	9. S	(19/2)(-)	17, 1	(0.611)		(0.740)		(1.358)	
54XE133	G 000.0	5.3 D	3/2 +	1, 1						
54XE133	M 233.	2.3 D	11/2 -	1, 1	2.415	3.12, 12	2.798	4.25, 14	4.588	5.13, 16

TABLE II (continued)

*** ISOMERIC STATE TO GROUND STATE INDEPENDENT YIELD RATIOS ***

					0.0-0.5MEV,JRMS=7.5		2.0MEV,JRMS=8.0		14.0MEV,JRMS=10.0	
NUCLEUS	STATE,EX	T(1/2)	J,P	REF,FOR	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF
56BA133	G 000.0	7.2 Y	(1/2)(+)	1, 3						
56BA133	M 287.	39. M	(11/2)(-)	1, 3	(3.272)		(3.786)		(6.179)	
53I 134	G 000.0	53. M	(4) (+)	17, 5						
53I 134	M 316.3	3.6 M	(8) (-)	17, 5	(0.737)		(0.885)		(1.590)	
54XE134	G 000.0	STABLE	0 +	17, 7						
54XE134	M 1965.0	0.29 S	7 -	17, 7	2.342		2.726		4.517	
55CS134	G 000.0	2.2 Y	4 (+)	1, 5						
55CS134	M 137.	2.9 H	8 (-)	1, 5	0.737		0.885		1.590	
54XE135	G 000.0	9.2 H	(3/2)(+)	3, 1						
54XE135	M 527.	15.6 M	(11/2)(-)	3, 1	(2.415)	1.68, 13	(2.798)	1.61, 15	(4.588)	1.79, 18
55CS135	G 000.0	3.E6 Y	7/2 +	3, 1						
55CS135	M 1621.	53. M	(19/2)(-)	3, 1	(0.611)		(0.740)		(1.358)	
56BA135	G 000.0	STABLE	3/2 +	3, 1						
56BA135	M 268.	28.7 H	11/2 -	3, 1	2.415		2.798		4.588	
56BA136	G 000.0	STABLE	0 +	3, 7						
56BA136	M 2040.	0.32 S	7 -	3, 7	2.342		2.726		4.517	

TABLE II (continued)

*** ISOMERIC STATE TO GROUND STATE INDEPENDENT YIELD RATIOS ***

					0.0-0.5MEV,JRMS=7.5		2.0MEV,JRMS=8.0		14.0MEV,JRMS=10.0	
NUCLEUS	STATE,EX	T(1/2)	J,P	REF,FOR	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF
56BA137	G 000.0	STABLE	3/2 +	1, 1						
56BA137	M 661.6	2.6 M	11/2 -	1, 1	2.415		2.798		4.588	
58CE137	G 000.0	9.0 H	3/2 +	3, 1						
58CE137	M 255.	34.4 H	11/2 -	3, 1	2.415		2.798		4.588	
58CE139	G 000.0	140. D	3/2 +	1, 1						
58CE139	M 746.	55. S	11/2 -	1, 1	2.415		2.798		4.588	
60ND141	G 000.0	2.51 H	3/2 +	1, 1						
60ND141	M 756.5	62.1 S	11/2 -	1, 1	2.415		2.798		4.588	
62SM141	G 000.0	11.3 M	1/2 (+)	1, 3						
62SM141	M	22.6 M	11/2 (-)	1, 3	3.272		3.786		6.179	
59PR142	G 000.0	19.2 H	2 -	1, 7						
59PR142	M 3.7	14.6 M	(5) (-)	1, 7	(2.342)		(2.726)		(4.517)	
62SM143	G 000.0	8.83 M	(3/2)(+)	1, 1						
62SM143	M 750.	65. S	(11/2)(-)	1, 1	(2.415)		(2.798)		(4.588)	
59PR144	G 000.0	17.3 M	0 -	1, 7						
59PR144	M 59.0	0.1 S	3 -	1, 7	8.884		10.174		16.172	

TABLE II (continued)

*** ISOMERIC STATE TO GROUND STATE INDEPENDENT YIELD RATIOS ***

					0.0-0.5MEV,JRMS=7.5		2.0MEV,JRMS=8.0		14.0MEV,JRMS=10.0	
NUCLEUS	STATE,EX	T(1/2)	J,P	REF,FOR	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF	R(CAL)	R(EXP),REF
61PM148	G 000.0	5.4 D	1 -	3, 7						
61PM148	M 75.7	42. D	6 -	3, 7	2.342		2.726		4.517	
63EU154	G 000.0	6.8 Y	3 -	5, 7						
63EU154	M L189.	45.8 M	(8) (-)	5, 7	(0.901)		(1.078)		(1.916)	
65TB156	G 000.0	5.4 D	(3) (-)	1, 8						
65TB156	M 88.4	5. H	(0) (+)	1, 8	(0.113)		(0.098)		(0.062)	
65TB158	G 000.0	(150Y)	(3) (-)	1, 8						
65TB158	M 111.	11. S	(0) (-)	1, 8	(0.113)		(0.098)		(0.062)	
67HO158	G 000.0	12. M	(5) (+)	1, 8						
67HO158	M 67.3	30. M	(2) (-)	1, 8	(0.427)		(0.367)		(0.221)	
67HO159	G 000.0	33. M	7/2 -	1, 4						
67HO159	M 205.9	8.3 S	(1/2) +	1, 4	(0.153)		(0.133)		(0.083)	
67HO160	G 000.0	25. M	(5) (+)	1, 8						
67HO160	M 60.1	5.0 H	(2) (-)	1, 8	(0.427)		(0.367)		(0.221)	
67HO161	G 000.0	2.5 H	7/2 -	3, 4						
67HO161	M 211.	6. S	1/2 +	3, 4	0.153		0.133		0.083	

TABLE II (continued)

*** ISOMERIC STATE TO GROUND STATE INDEPENDENT YIELD RATIOS ***

NUCLEUS	STATE,EX	T(1/2)	J,P	REF,FOR	0.0-0.5MEV,JRMS=7.5 R(CAL)	R(EXP),REF	2.0MEV,JRMS=8.0 R(CAL)	R(EXP),REF	14.0MEV,JRMS=10.0 R(CAL)	R(EXP),REF
67HO162	G 000.0	11.8 M	1 +	3, 7						
67HO162	M (100.)	68. M	(6) (-)	3, 7	(2.342)		(2.726)		(4.517)	
67HO163	G 000.0	33. Y	(7/2) -	1, 4						
67HO163	M 299.	1.08 S	(1/2) +	1, 4	(0.153)		(0.133)		(0.083)	
66DY165	G 000.0	2.35 H	7/2 +	1, 4						
66DY165	M 108.2	1.255M	1/2 -	1, 4	0.153		0.133		0.083	
67HO166	G 000.0	26.9 H	0 -	3, 7						
67HO166	M 9.0	1.2E3Y	(7) (-)	3, 7	(2.342)		(2.726)		(4.517)	
68ER167	G 000.0	STABLE	7/2 +	1, 4						
68ER167	M 207.9	2.3 S	1/2 -	1, 4	0.153		0.133		0.083	
70YB169	G 000.0	31. D	7/2 +	1, 4						
70YB169	M 24.2	50. S	1/2 -	1, 4	0.153		0.133		0.083	
71LU169	G 000.0	34. H	7/2 +	1, 4						
71LU169	M 29.0	2.7 M	(1/2)(-)	1, 4	(0.153)		(0.133)		(0.083)	
71LU170	G 000.0	2.0 D	0 +	1, 5						
71LU170	M 93.0	0.7 S	4 -	1, 5	5.572		6.385		10.169	

*** TABLE II REFERENCES ***

1 D.J. HOHEN AND W.B. EWBANK,NUCLEAR LEVEL SCHEMES A=45 THROUGH A=257 FROM NUCLEAR DATA SHEETS,ED. BY NUCLEAR DATA GROUP O .R.N.L.,ACAD. PRESS N.Y.(1973)

2 R. IAFIGICLA AND J.K.P. LEE,ISOMERS 84YM AND 85ZRM,PHYS. REV. C13,2075(1976).

3 C.M. LEDERER,J.M. HOLLANDER,AND I. PERLMAN,TABLE OF ISOTOPES (SIXTH EDITION), J. WILEY AND SONS, N.Y.(1967).

4 H.A. SMITH, M.E. BUNKER,J.W. STARNER, AND C.J. ORTH, STATES IN 126SB POPULATED IN THE BETA DECAY OF 10EXP5-YR 126SN, PHY S.REV. C13,387(1976).

5 Y.Y. CHU AND E.M. FRANZ, CONVERSION ELECTRON STUDIES ON THE NEW HIGH SPIN ISOMER IN 154EU. PHYS. REV. C13,2011(1976).

6 I.F. CROALL AND H.H. WILLIS, THE YIELDS OF THE ISOMERS OF 81SE AND 83SE IN THE THERMAL NEUTRON FISSION OF 239PU, J. INOR G. NUCL. CHEM. 25,1213(1963).

7 K. KRIEN,E.H. SPEJEWSKI,R.A. NAUMANN,AND H. HUBEL, ELECTRON CAPTURE DECAY OF 105MAG. PHYS. REV. C6,1847(1972).

8 K. WOLFSBERG, ESTIMATED VALUES OF FRACTIONAL YIELDS FROM LOW ENERGY FISSIONAND A COMPILATION OF MEASURED FRACTIONAL YIEL DS, LOS ALAMOS SCIENTIFIC LABORATORY REPORT LA-5553-MS,(MAY 1974). R IS AVG. OF VALUES REPORTED FOR 233U AND 235U,RANGE IS 1.80 L.T. R L.T. 2.47.

9 IBID., R IS AVG. OF VALUES REPORTED FOR 233U AND 235U, RANGE IS 1.55 L.T. R L.T. 3.11.

10 IBID., R IS SINGLE VALUE REPORTED FOR 235U.

11 IBID., R IS SINGLE VALUE REPORTED FOR 235U.

12 IBID., R IS AVG. OF VALUES REPORTED FOR 233U, 235U, 239PU, AND 242AM, RANGEIS 2.40 L.T. R L.T. 3.52.

13 IBID., R IS AVG. OF VALUES REPORTED FOR 233U, 235U, 239PU, AND 242AM, RANGEIS 1.40 L.T. R L.T. 2.07.

14 IBID., R IS AVG. OF VALUES REPORTED FOR 235U AND 239PU, RANGE IS 3.78 L.T. R L.T. 4.72.

15 IBID., R IS AVG.OF VALUES REPORTED FOR 235U AND 239PU, RANGE IS 1.35 L.T. R L.T. 1.87.

16 IBID., R IS SINGLE VALUE FOR 235U.

17 C.M. LEDERER, LAWRENCE BERKELEY LABORATORY, PRIVATE COMMUNICATION (APRIL 1976).

18 K. WOLFSBERG, ESTIMATED VALUES OF FRACTIONAL YIELDS FROM LOW ENERGY FISSIONAND A COMPILATION OF MEASURED FRACTIONAL YIEL DS, LOS ALAMOS SCIENTIFIC LABORATORY REPORT LA-5553-MS,(MAY 1974). R IS SINGLE VALUE FOR 235U.