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Title: Technique for the Identification of Dominant Delayed Neutron Precursors

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Technique for the Identification of Dominant Delayed Neutron Precursors

by

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1. Introduction

A technique for the identification of delayed neutron precursors has been developed based on the product of cumulative yield and probability of neutron emission. The motivation behind this work is to fix the decay constants of delayed neutrons to those of the dominant delayed neutron precursors. The desirability of identifying a single set of decay constants that would apply to all fissionable isotopes and be independent of the neutron energy spectrum has been addressed by several authors.[1,2] The main advantages of a fixed-decay constant representation are simplifying the analysis of epithermal and fast reactors with multiple fissioning isotopes, and improving the fit to experimental data while preserving the inferred positive reactivity scale associated with the original six-group representation.

It is well known that 271 delayed neutron precursors exist, but only a select number of those precursors contribute significantly to the decay of delayed neutrons.[3] Using data compiled by England and Rider, which lists fission yield and probability of neutron emission values for the 271 known delayed neutron precursors in 32 fissioning systems, thirteen precursors were identified that are consistently dominant for all fissioning systems.

2. Identification of Delayed Neutron Precursors

The precursor yields that are listed by England and Rider are cumulative; that is, they indicate the total time-integrated decays of each precursor per fission accounting for both prompt precursor production and delayed production.[4] The product of a precursor's cumulative yield and its P_n value is the cumulative delayed neutron yield associated with the precursor. This yield-P_n product can be used to assess the relative importance of different precursors. Figure 1 shows the dominant delayed neutron precursors for the fast fission of U-235. The yield-P_n product is plotted against the half-life of the 271 known delayed neutron precursors. From Figure 1, Br-87 is clearly the only precursor that contributes significantly to group 1. On the other hand, I-137 and Br-88 are both significant contributors to group 2. For all 32 fissioning systems included in the England and Rider database, Br-87, I-137, and Br-88 are the three longest-lived dominant precursors. To substantiate the dominant contributions of Br-87, I-137, and Br-88, experimental decay data for U-235 and Np-237 was reanalyzed.[5]

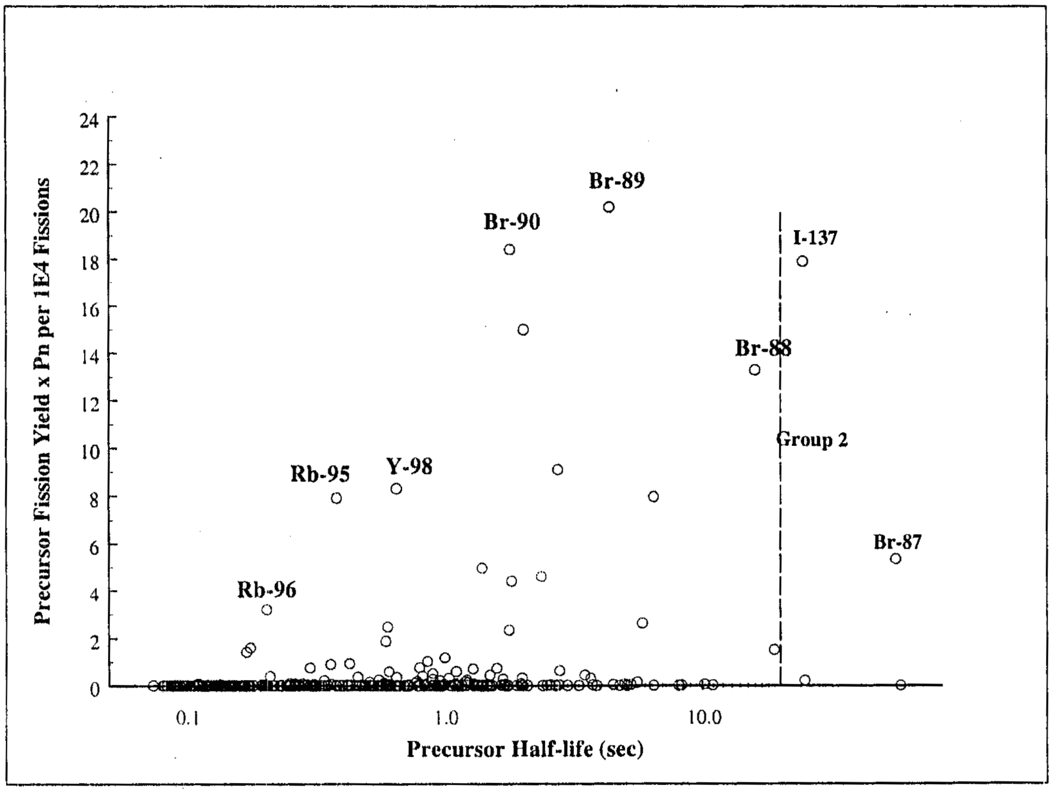

Figure 1. Dominant Delayed Neutron Precursor for U-235F

The seven-group representation used in this paper differs from the traditional six-group representation by splitting traditional group 2 between Br-88 and I-137, as indicated in Figure

1. The dominant precursors for 12 of the most important fissioning systems are indicated in Table I. For all 32 fissioning systems included in the database, the 13 precursors listed in Table I are dominant. Br-87 is the dominant precursor in group 1. Iodine-137 and Br-88 are dominant in traditional group 2. For the proposed seven-group formulation, the dominant precursor in group 2 is I-137, and the dominant precursor in proposed group 3 is Br-88.

The relative importance ranks within groups 3, 4, and 5 (proposed groups 4, 5, and 6) change from one fissioning system to another, as indicated by the numbers in parentheses in Table I. With various permutations in rank, I-138, Rb-93, and Br-89 consistently dominate group 3 (proposed group 4). Rubidium-94, I-139, and Br-90 consistently dominate group 4 (proposed group 5). Yttrium-98, Br-91, and Rb-95 consistently dominate group 5 (proposed group 6). The dominant precursor in group 6 (proposed group 7) is Rb-96.

3. Methodology to identify dominant precursors

Table I suggests a seven-group representation in which the decay constants of a dominant precursor would be used. The dominant precursors in groups 1, 2, 3 and 7 are Br-87, I-137, Br-88 and Rb-96, respectively. No single precursor consistently dominates proposed groups 4, 5, or 6 for all fissioning systems. A sensitivity analysis was, therefore, devised to identify a suitable dominant precursor for each of these groups. The first alternative investigated uses the half-lives of Br-89, Br-90, and Rb-95, which are the dominant precursors with the shortest half-lives (see Table I) in proposed groups 4, 5, and 6. Alternative 2 uses the corresponding dominant precursors Rb-93, I-139 and Br-91 with intermediate half-lives. Alternative 3 uses the corresponding longest-lived dominant precursors I-138, Rb-94, and Y-98.

Each of the three seven-precursor alternatives was tested by transforming six-group yields and decay constants for 12 fissioning systems, and then comparing the delayed neutron component of the inhour equation for the resulting seven-precursor models with those for the original six-group models. After performing the sensitivity analysis, alternative 2 resulted with the

Table I. Dominant Precursors by Fission-yield-P_n Product.

	Delayed Neutron Group												
Original	1	2		3			4			5			6
Proposed	1	2	3	4			5			6			7
	Dominant Precursor												
Precursor	Br-87	I-137	Br-88	I-138	Rb-93	Br-89	Rb-94	I-139	Br-90	Y-98	Br-91	Rb-95	Rb-96
Half-life (s)	55.9	24.5	16.4	6.5	5.85	4.4	2.71	2.3	1.9	0.59	0.54	0.377	0.199
Fissioning System	Rank Within Group by Fission-Yield-P_n Product												
Th-232F	(1)	(1)	(1)	(2)	(3)	(1)	(3)	(1)	(2)	(3)	(1)	(2)	(1)
U-233F	(1)	(1)	(1)	(2)	(3)	(1)	(2)	(1)	(3)	(1)	(3)	(2)	(1)
U-233T	(1)	(1)	(1)	(2)	(1)	(3)	(1)	(2)	(3)	(1)	(3)	(2)	(1)
U-235F	(1)	(1)	(1)	(1)	(3)	(2)	(3)	(2)	(1)	(1)	(3)	(2)	(1)
U-235T	(1)	(1)	(1)	(2)	(3)	(1)	(3)	(1)	(2)	(2)	(3)	(1)	(1)
U-238F	(1)	(1)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(3)	(2)	(1)	(1)
Np-237F	(1)	(1)	(1)	(2)	(3)	(1)	(1)	(2)	(3)	(1)	(2)	(3)	(1)
Pu-239F	(1)	(1)	(1)	(1)	(3)	(2)	(1)	(2)	(3)	(1)	(3)	(2)	(1)
Pu-239T	(1)	(1)	(1)	(1)	(3)	(2)	(1)	(3)	(2)	(1)	(3)	(2)	(1)
Pu-240F	(1)	(1)	(1)	(2)	(3)	(1)	(1)	(3)	(2)	(1)	(3)	(2)	(1)
Pu-241F	(1)	(1)	(1)	(1)	(3)	(2)	(1)	(3)	(2)	(1)	(3)	(2)	(1)
Pu-242F	(1)	(1)	(1)	(1)	(3)	(2)	(1)	(2)	(3)	(1)	(3)	(2)	(1)

smallest maximum relative difference. For this reason, it is proposed that decay constants of the precursors associated with alternative 2 be used in lieu of empirically determined group decay constants. These precursors are Br-87, I-137, Br-88, Rb-93, I-139, Br-91, and Rb-96.

4. Conclusion

This study identified thirteen delayed neutron precursors that are consistently dominant out of 271 precursors for 32 fissioning systems. A rationale for using the decay constants of 7 of these dominant precursors in lieu of empirically determined decay constants has been presented. When the transformation used to develop this rationale is applied to widely used six-group reactivity models for important fissioning systems, the original positive reactivity scale is maintained. The goodness of fit to experimental delayed neutron decay data improved by using linear least squares with the suggested fixed decay constants instead of nonlinear least squares in which both decay constants and abundances are estimated.

5. References

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