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ISOMERIC YIELDS OF ^{130}Sb, ^{132}Sb, ^{134}I, AND ^{136}I IN THE THERMAL NEUTRON FISSION OF ^{235}U

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Isomer yield ratios of ^{130}Sb, ^{132}Sb, ^{134}I and ^{136}I isomers formed in the thermal neutron fission of ^{235}U have been calculated from our previous experimental studies that led to the identification of these species. In those studies the iodine and antimony fractions formed in fission were rapidly separated and the decay of γ-rays belonging to each isomer pair were followed using Ge(Li) detectors and a multichannel analyzer. The isomer ratios were calculated from growth and decay considerations of these γ-rays. The results are compared with the recently published values obtained with an on-line isotope separator, those from LOHENGRIN, and those from model calculations. Angular momenta of fission fragments corresponding to the measured isomer yields have also been calculated.

INTRODUCTION

Isomer yield ratio measurements in fission provide information about the intrinsic angular momentum and scission point deformation of fission fragments. Several isomer ratio measurements were carried out for medium and

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high energy fission[1-11] and thermal neutron fission[12-16]. Furthermore, an extensive study of fission product yields in the thermal neutron fission of ^{235}U using an on-line isotope separator has been recently published by Rudstam et al.[17]. Madland and England[18] used a simple statistical model for calculating isomer yield ratios of products formed in neutron induced fission.

In this work we report the isomer yields of 40-min and 6.5-min ^{130}Sb, 2.8-min and 4.2-min ^{132}Sb, 3.5-min and 52.6-min ^{134}I and 46-sec and 83-sec ^{136}I isomers, extracted from our previous experimental studies, which led to the identification and characterization of these species[19-22]. The results are compared with recent experimental results and those from model calculations.

EXPERIMENTAL

In our aforementioned studies, iodine and antimony species were rapidly separated from the thermal neutron fission products using radiochemical techniques. Tipically 2.0 mg of 93.5% enriched ^{235}U samples were irradiated for 15 sec in a flux of 2×10^{13} $n \cdot cm^{-2} \cdot sec^{-1}$. Counting was started about 1-2 min after irradiation.

The γ-ray spectra of iodine and antimony samples were observed with 18-45 cm^3 Ge(Li) detectors whose FWHM values for the 662-keV γ-ray of ^{137}Cs were ≤2.8 keV. They were used in conjunction with a 4096-channel analyzer.

The ratio of the independent yields of the ^{130}Sb, ^{132}Sb, ^{134}I and ^{136}I isomers were determined by following the decay of the 793-keV, 697.4-keV, 847-keV and the 1313.3 keV γ-rays arising from the decay of both isomers in each case, respectively, and by using ap-

TABLE 1

Independent yields (IY) of antimony and iodine species in $^{235}U(n_{th}, f)$ determined in this work

Nuclide	IY (%) (This work)	Rudstam et al.[17]
^{130g}Sb	0.19±0.05	0.204±0.027
^{130m}Sb	0.29±0.09	-
^{132g}Sb	0.68±0.20	0.34 ±0.03
^{132m}Sb	1.40±0.42	1.32±0.14
^{134g}I	0.36±0.04	1.2 ±1.0
^{134m}I	0.50±0.07	0.28±0.03
^{136g}I	1.72±0.69	0.29±0.24
^{136m}I	2.25±0.91	1.09±0.12

propriate growth and decay equations and the known decay schemes of the isomers[19-22]. The isomer ratios as well as individual independent yields were calculated.

RESULTS AND DISCUSSION

The results of the independent yield measurements of antimony and iodine species in the thermal neutron fission of ^{235}U are given in Table 1.

Also given are the experimental results of Rudstam et al.[17] obtained with an on-line isotope separator. For the antimony species the radiochemical and the instrumental methods gave comparable results, whereas for the iodine species serious discrepancies exist.

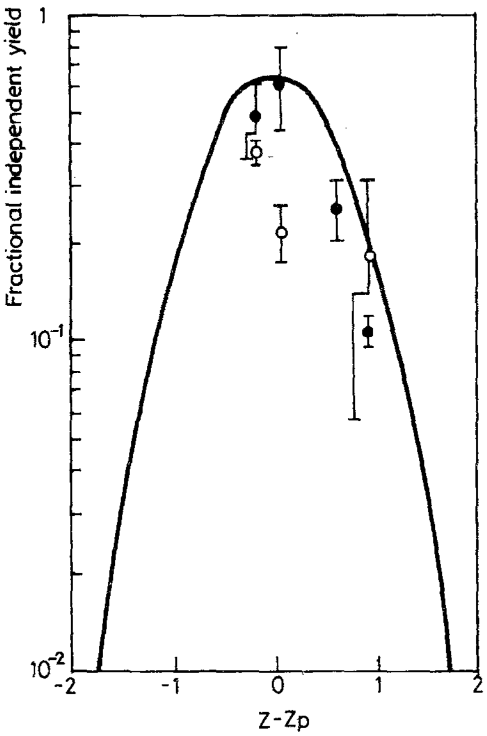

Fig. 1. Experimental fractional independent yields from this work (full, circles), those from Rudstam et al.[17] (open circles) and the normal charge distribution curve from systematics using the extended Zp model of Wahl[23] with σ_Z=0.531 and even-odd neutron and proton factors set as 1

The experimental fractional independent yield data are plotted in Fig. 1 as a function of Z-Zp where the most probable charge, Zp, values were taken from the results of the extended Zp model of Wahl[23]. The curve shown represents a normal Gaussian charge dispersion with width parameter $\sigma_Z = 0.531$, without odd-even proton and neutron effect modulation.

The negative deviations of the experimental points of this work from the normal curve result from the odd-

odd nature of the species studied. The odd-odd factor F(A) for the nuclides of interest is thus estimated as 0.73.

The experimental isomer yield ratios from this work, from Rudstam et al.[17] as well as those calculated using the Madland and England[18] model are given in Table 2. Also given are the values obtained by the mass separator LOHENGRIN at the mean kinetic energy of the fragments[24].

Generally within experimental errors, our results are consistent with those obtained from model calculations. The results using LOHENGRIN with the possible exception of ^{134}I isomers, are also in accordance with our radiochemical measurements. No agreement seems to exist however with the values of Rudstam et al[17]. Their quite large uncertainties probably arise from the experimental technique employed.

The isomeric yield ratios given in Table 2 were converted into fragment angular momenta (J_{rms}) using again the Madland and England model[18]. In this model the initial angular momentum distribution is assumed to be of the form

$$P(J) \propto (2J + 1)\exp - \frac{J(J+1)}{B^2}$$

Here $B \cong J_{rms}$. The model is simple, with no corrections for prompt neutron emission or for cascade γ-emission. The results obtained are given in Table 3.

The average J_{rms} obtained from values given in Table 3 is 7.6. This angular momentum is in very good agreement with the value of 7.5 assumed for all thermal neutron fission products in ^{235}U fission by Madland and England[18]. Furthermore, the rather high values are an indication of appreciable deformation of fragments at scission.

TABLE 2

Independent yield ratios of isomers formed in the thermal neutron fission of ^{235}U

Isomer pair	Spin values		Y^i_m/Y^i_g			
	m	g	This work	Rudstam et al.[17]	LOHENGRIN measurements[24]	Madland and England [18]
^{130}Sb	8	4	0.66±0.25	-	-	0.74
^{132}Sb	4	8	2.1 ±0.8	3.9 ±0.5	2.2 ±0.3	1.36
^{134}I	8	4	1.4 ±0.7	0.23±0.19	0.39±0.10	0.74
^{136}I	6	2	1.3 ±0.5	3.8 ±3.1	2.1 ±0.5	1.80

TABLE 3

Isomeric yield ratios and corresponding angular momenta from this work

Isomer pair	Spin values		Y^i_m/Y^i_g	J_{rms} (ħ)
	m	g		
^{130}Sb	8	4	0.66±0.25	7.5±0.8
^{132}Sb	4	8	2.1 ±0.8	6.9±0.7
^{134}I	8	4	1.4 ±0.7	9.5±0.9
^{136}I	6	2	1.3 ±0.5	6.6±0.7

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