



Spectroscopy of fission products for forensics

NNDC - BNL



Experimental campaign: Background

- The most common way to identify fission products and determine their yield, is to measure the characteristic γ-rays emitted in their decay ("activation technique")
- This technique fully relies on a solid knowledge of nuclear decay data (*i.e.*, γ-ray energy and intensities), as well as fission yields
- Experimental campaign to accurately measure decay data of selected fission products relevant to Nuclear Forensics







Previous Experience with Medical Isotopes

A striking **example** of the sensitivity and the improvements to the decay schemes that can be achieved with modern arrays is given by ⁸⁶Y β^+ -decay

Our study identified 52 new excited levels and over 100 new γ -ray transitions

The **511-keV intensity** (useful for diagnostics purposes) **decreases** by 15%







Lanthanum-140

- along with Ba-140, is a well-known chronometer used to date a nuclear event
- evaluated intensities originate from a single publication from 1991





M. Jandel, P. Bender

Production & Assay

- Radioactive ¹⁴⁰La was produced at the UMass Lowell research reactor via (n,g) on ^{nat}La
- The source was shipped to ANL for assay in **Gammasphere** (~ 3 days)



La-140 Analysis

- Consistent Matrix and Singles intensities - in most cases confirm the ENSDF intensities (1991CH05)
- ~10 proposed new transitions
- γ - γ angular correlation

taken up by 3 SULI interns over the summer/fallJ. OcheltreeN. CabanasN. Joseph











Iodine-130

- "blocked" fragment, highly-sensitive to fuel/n-energy changes
- ENSDF based on a 1973 measurement, with more recent experiments reporting intensities disagreeing by as much as 10%

131Ba 11.50 D a: 100.00%	132Ba >3.0E+21 Y 0.101% 28	133Ba 10.551 Y a: 100.00%	134Ba STABLE 2.417%	135Ba STABLE 6.592%	136Ba STABLE 7.854%	137Ba STABLE 11.232%	138Ba STABLE 71.69895	139Ba 83.06 M β-: 100.00%
130Cs 29.21 M ε: 98.40% β-: 1.60%	131Cs 9.689 D 8: 100.00%	132Cs 6.480 D ε: 98.13% β-: 1.87%	133Cs STABLE 100%	134Cs 2.0652 Υ β-: 100.00% ε: 3.0E-4%	139Cs 2.3E+6 Υ β-: 100.00 b	136Cs 13.04 D β-: 100.00%	137Cs 30.08 Υ β-: 100.00%	138Cs 33.41 M β-: 100.0095
129 %e STABLE 26.4006%	1 30Xe STABLE 4.071095	131Xe STABLE 21.232%	132Xe STABLE 26.9086%	133 Xe 5.2475 D β-: 10.00%	134 Χε >5.8E+22 Υ 10.43579b 2β-	135 Χ- 9.14 H β-: 100.00%	136 Xe >2.4E+21 Υ 8.857395 2β-	137Xe 3.818 M β-: 100.00%
1281 24.99 M β-: 93.1095 δ: 6.90%	1291 1.57Ε+7 γ β-: 100.0 8	1301 12.36 H β-: 100.00%	1311 8.0252 D β-: 100.00%	1321 2.295 H β-: 100.00%	1331 20.83 H β-: 30.00%	134I 52.5 M β-: 100.00%	1351 6.58 H β-: 100.00%	1361 83.4 S β-: 100.00%
127Te 9.35 H β-: 100.00%	128Te 2.41E+24 Y 31.74% 2β-: 100.00%	129Te στ β-: 100.00%	130Te ≥3.0E+24 Y 34.08% 2β-: 100.00%	131Te 25.0 M β-: 100.00%	132Te 3.204 D β-: 100.00%	133Te 12.5 M β-: 100.00%	134Te 41.8 M β-: 100.00%	135Te 19.0 S β-: 100.00%







Energy (keV)	lg (1973Ho25)	lg (1999SaZW)
417.9	34.5(10)	26.5(9)
668.5	97(3)	90(7)
1157.4	11.4(4)	8.2(6)

lodine-130

Production & Assay

- Purchase of enriched ¹³⁰Te and production of the irradiation target (J. Greene, ANL)
- ¹³⁰I was produced at the BNL Tandem Van de Graaff via 7.5 MeV ¹³⁰Te(p,n)
- The source was shipped to ANL for assay in Gammasphere (~ 1 day)











- 2 new levels
- 23 new transitions
- 3 re-placed transitions





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7.934.5(10)26.5(9)34.5(5)8.597(3)90(7)97.4(14)	ergy (keV)	lg (1973Ho25)	lg (1999SaZW)	Present Work	
8.5 97(3) 90(7) 97.4(14)	.9	34.5(10)	26.5(9)	34.5(5)	
	3.5	97(3)	90(7)	97.4(14)	
57.4 11.4(4) 8.2(6) 11.52(18)	7.4	11.4(4)	8.2(6)	11.52(18)	



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- $T_{1/2} = 12.36(1)$ hrs





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FY 2022 - planned measurements

I-135/Xe-135

- ¹³⁵Xe has been identified for continuous monitoring for CTBT applications thanks to its low reactivity
- ¹³⁵I yield remains nearly constant for all fission targets / energies (reference for other lodine isotopes)
- ¹³⁵Xe decay is based on one hand-written private communication from 1974

	° Xe						1974MEZV			
	Et GEN			Iz (arg)			Inor ang		lg	
_	158.	Z 97	(9)	3.	21(5)) 4.17	.377	467	294	
_	200.	194	(95)	0	13(5)	.012	608	40-	
	249.	794	(1)	= /000	,	1070	962	249	p	
	35A.	391	(30)	2	45(5)	2,51	.227	608	2.9	





FY 2022 - planned measurements

Cerium-143

- particulate fission product monitored as part of CTBT, and - along with other A=143 isotopes, important for predictions of inventory in used fuel assemblies
- evaluated data originate from a single experiment performed in 1989





production through neutron irradiation of a sample of ^{nat}Ce at the **UMass Lowell** research **reactor**



αβγ decay station being commissioned at NNDC - BNL







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