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X-ray intensity data in the ENSDF database

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Background

- ❑ For ENSDF, currently we do not evaluate or provide X-ray intensity data in the decay datasets
- ❑ Users can retrieve using Web tools, like NuDAT or LiveChart
- ❑ At the NSDD, it has been decided to list the atomic data, like Auger electrons and X-ray.
- ❑ In the Table of Radioactive Isotopes (1986BrZQ), recommended X-ray data are calculated values
- ❑ In DDEP, the recommended value is either from calculation or measurements
- ❑ As we are in the implementation phase of including the atomic data in the ENSDF decay datasets – a few observations on X-ray data are presented.

X-ray data in the ENSDF:

□ Experimental data

- X-ray energy, relative or absolute intensity are listed
- In table or above the common sections in the data set
- Used for decay data normalization

□ No recommended data for X-rays

- in general K_{α} , K_{β} subshell X-ray intensities are stronger and used as characteristic X-rays of an element
- Other subshell intensities can be higher

□ X-ray data can be retrieved through web tools, like NuDAT or LiveChart

- NuDAT (notes?)
- Livechart (some notes are available)

^{235}U α decay (7.04×10^8 y)

I(Th L_1 x-rays)=0.599 15 (absolute), 1.039 26 (relative) (2017Le03).
 I(Th L_{α} x-rays)=20.26 44 (absolute), 35.2 8 (relative) (2017Le03).
 I(Th L_{β} x-rays)=17.42 38 (absolute), 30.2 6 (relative) (2017Le03).
 I(Th L_{γ} x-rays)=2.43 5 (absolute), 4.22 9 (relative) (2017Le03).
 I(Th total L x-rays)=40.7 10 (absolute), 70.7 17 (relative) (2017Le03).
 I(Th $K_{\alpha 2}$ x-rays)=3.73 19 (absolute), 6.48 35 (relative) (2017Le03).
 I(Th $K_{\alpha 1}$ x-rays)=4.62 24 (absolute), 8.03 43 (relative) (2017Le03).
 I(Th $K_{\beta 1}$ x-rays)=1.46 8 (absolute), 2.63 14 (relative) (2017Le03).
 I(Th $K_{\beta 2}$ x-rays)=0.431 22 (absolute), 0.748 40 (relative) (2017Le03).

Measured energies and absolute intensities of x rays (1996Ru11):

I(Th, $K_{\alpha 1}$): E(x ray)=93.35, I(x ray)=5.56% 14.

I(Th, $K_{\beta 1}$): E(x ray)=105.6, I(x ray)=1.17% 5.

2022Si29

^{241}Am α decay

M x-rays:	6.3% 6	1971Ka48
L x-rays:	37.7%	1957Ma17
	37.3% 18	1971Ge11
	38.9% 20	1971Wa28
	38.2% 8	1974Ca16
	37.9%	1976GuZN
	45.0%	1977Hs02
	38.3% 10	1988SeZR
	37.7% 19	1992Bl07
K x-rays:	0.0040%	1976GuZN

2006Ba41

Notes: Livechart (web tool)

Livechart

• Atomic radiation fields

E energy of the radiation in keV. For X-rays and Auger electrons, an energy range is given for transitions grouping various atomic sub-shells. For conversion electrons the energy is averaged over the contributing sub-shells and it is calculated using the **Brlcc** code

I(abs) absolute intensity of the radiation in %

Origin atomic shell emitting the radiation

Line IUPAC notation of the transition.

γ , **EC energy** Energy of the gamma transition or electron capture respectively, causing the X-ray or electron emission

P_{shell} Electron capture probability for the given β transition

α_{shell} Conversion coefficient for the given γ transition

X-ray data in the DDEP:

□ Experimental data

- X-ray energy, relative or absolute intensity are evaluated and listed

□ Recommend data from the evaluation

- Using codes, like RADLST, EMISSION
- Or from the measured data
- Associated data, like $P_{k,L}$, $\omega_{k,L}$, $n_{k,L}$, etc., are documented

□ Available from the published pdf or individual isotopic decay data from web retrieval

- Isotopic decay data – Table and Comments – two separate documents

KRI/V. P. Chechev, N. K. Kuzmenko 2002

²⁴¹Am α decay

From the Comments document

	1976GuZN (measured) ^a	Recommended (calculated)
K α_2	0,001 18 (4)	0,001 134 (30)
K α_1	0,001 89 (6)	0,001 81 (5)
K β_1	7,1 (3) 10 ⁻⁴	6,58 (21) 10 ⁻⁴
K β_2	2,29 (15) 10 ⁻⁴	2,26 (8) 10 ⁻⁴

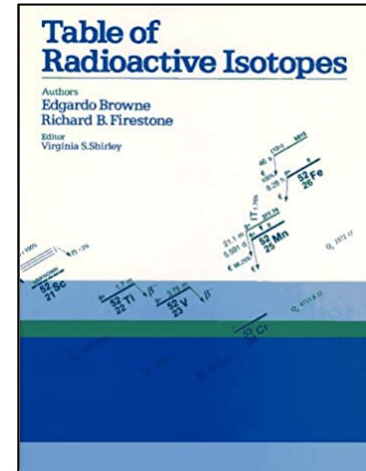
6.1 X-Ray Emissions

From the Table document

		Energy keV	Photons per 100 disint.	
XL	(Np)	11,89 — 22,2	37,66 (17)	
XK α_2	(Np)	97,069	0,001134 (30)	} K α
XK α_1	(Np)	101,059	0,00181 (5)	
XK β_3	(Np)	113,303	}	} K' β_1
XK β_1	(Np)	114,234	0,000658 (21)	
XK β_5''	(Np)	114,912	}	
XK β_2	(Np)	117,463	}	} K' β_2
XK β_4	(Np)	117,876	0,000226 (8)	
XK $O_{2,3}$	(Np)	118,429	}	

Table of Radioactive Isotopes (1986BrZQ):

- ☐ Recommend data from the evaluation
 - Based on the decay data and calculations (Notes and Appendix)



Photons (^{235}U)
(continued)

γ_{mode}	$\gamma(\text{keV})$	$\gamma(\%)^\dagger$
γ [M1+~20%E2]	31.585 ¹⁴	0.016 ⁵
γ [M1]	41.13 ¹⁸	~0.03
γ [E2+~20%M1]	41.954 ¹²	~0.04
γ [E2]	51.179 ¹⁴	~0.020
γ [M1+E2]	54.201 ¹⁸	<0.030
γ [M1+E2]	64.348 ²¹	~0.020
γ [E2]	72.71 ¹⁸	~0.11
γ [E1]	74.98 ³	0.06 ¹
Th $K_{\alpha 2}$	89.955	3.36 ²¹
Th $K_{\alpha 1}$	93.350	5.5 ³
γ [M1+E2]	95.72 ⁸	
γ [E2]	96.154 ¹⁶	0.086 ¹¹
Th $K_{\beta 1}'$	105.362	1.98 ¹²
Th $K_{\beta 2}'$	108.990	0.66 ⁴

Photons (^{241}Am)
(continued)

γ_{mode}	$\gamma(\text{keV})$	$\gamma(\%)$
Np $K_{\alpha 2}$	97.066	0.00126 ¹¹
γ [E2]	98.944 ²¹	0.020 ²
Np $K_{\alpha 1}$	101.059	0.00201 ¹²
γ [M1+E2]	101.43 ⁶	
γ [E1]	102.952 ¹⁰	0.0195 ¹⁰
γ [E2]	109.76 ⁴	~2 × 10 ⁻⁵ ⁷
Np $K_{\beta 1}'$	113.944	0.00074 ⁶
Np $K_{\beta 2}'$	117.891	0.000249 ²²
γ [E2]	122.080 ¹²	0.0010 ¹

^{235}U α decay [$T_{1/2}=7.04\times 10^7$ y (1)]:

□ %I($K_{\alpha 1}$ X-ray): 93.35 keV

Based on the ENSDF (2022)

NuDAT (web tool): 4.7 (5) – 10.6%

LiveChart (web tool): ≈ 4.8

JAVA_RADLST: 4.8 (6) - 12%

paceENSDF – same as NuDAT

DDEP (2008): 5.75 (11) – 1.9%

RADLST – DDEP

CNDC /Huang Xiaolong, Wang Baosong

□ %I($K_{\alpha 1}$ X-ray): 93.35 keV

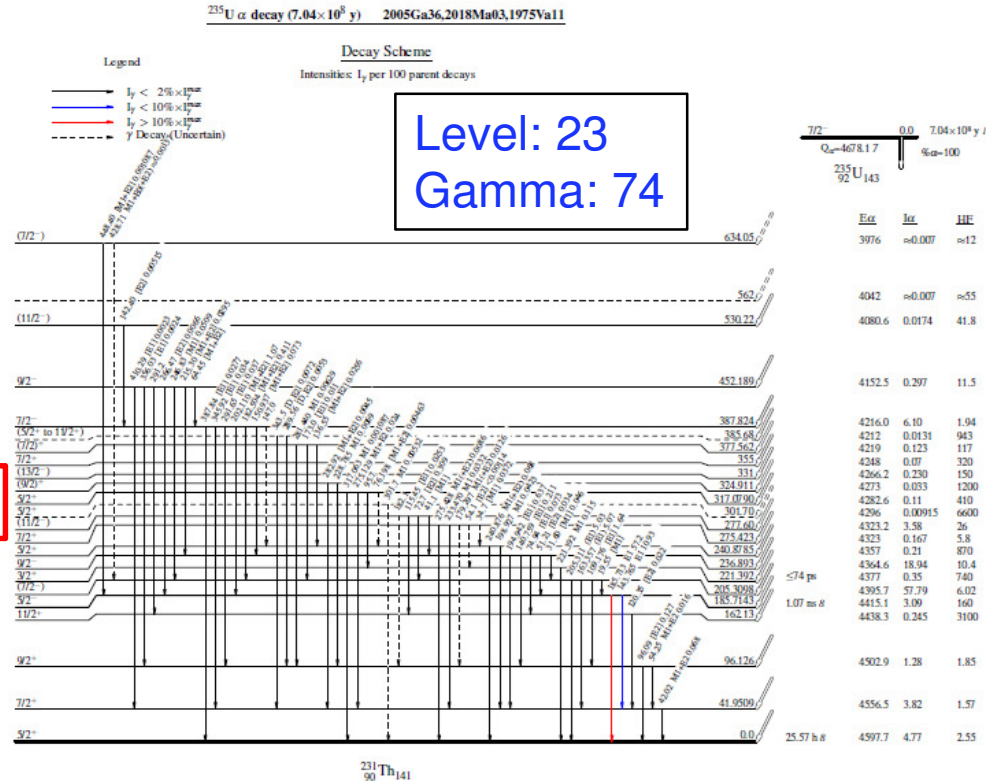
Measurements:

1996Ru11: 5.56 (14) – 2.5%

2017Le03: 4.62 (24) – 5.2%

2001Br31 and 2013Br04 – minor variation - 2005Ga36 study

2022Si29: a dedicated and precise gamma-ray and conversion electron spectroscopic study is needed for a better understanding and completeness of the decay scheme



^{241}Am α decay [$T_{1/2}=432.6$ y (6)]:

□ %I(K X-ray): L X-ray intensity is stronger

Based on the ENSDF (2006)

NuDAT (web): 0.0038 (1) – 2.5%

LiveChart (web): 0.0039 (1) – 2.5%

$\alpha_{1,2}$ JAVA_RADLST: 0.00299 (6) – 2.0%

paceENSDF – same as NuDAT

DDEP (2002): 0.00382 (10) – 2.5%

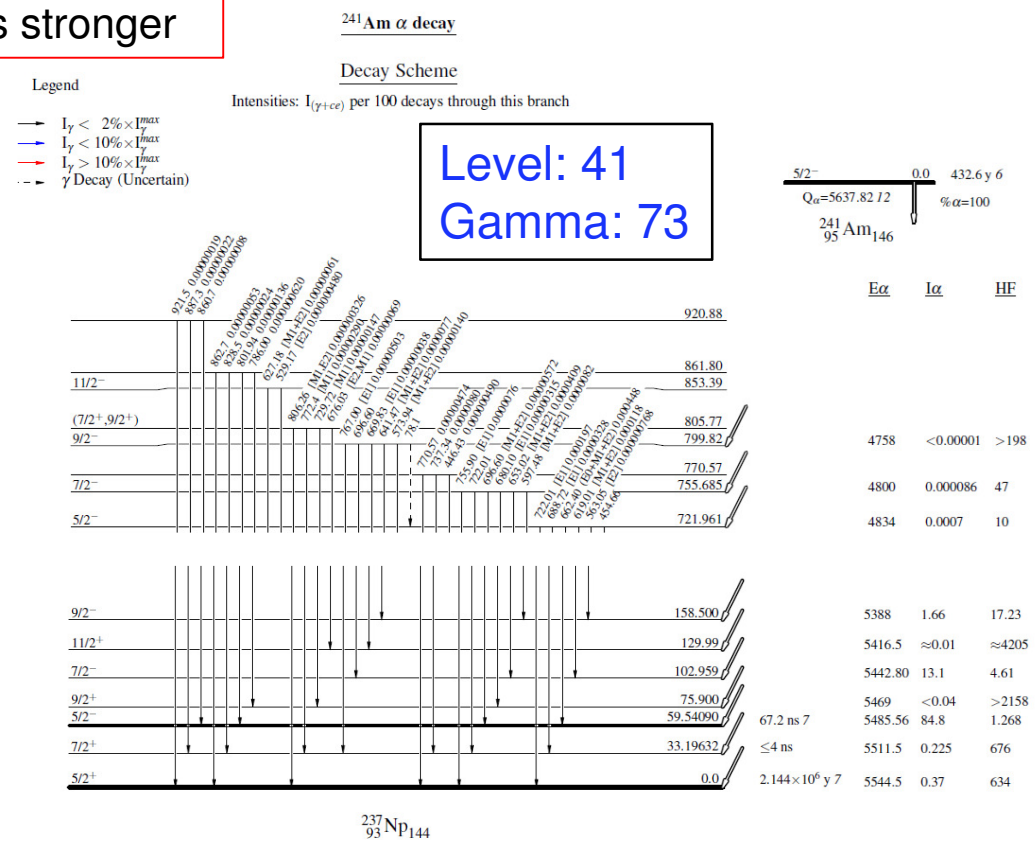
EMISSION computer program – DDEP

KRI/V. P. Chechev, N. K. Kuzmenko

□ %I(K X-ray):

Measurement:

1976GuZN: 0.00401 (10) – 2.5%



2006Ba41



Observations:

- ❑ Inclusion of X-ray data is currently in the implementation phase for decay datasets in the ENSDF
- ❑ At present, users can obtain these data using a web tool (NuDAT, Livechart, paceENSDF, etc.)
 - Not available in the Nuclear Data Sheets
- ❑ In the DDEP and Table of Radioactive Isotopes (1986) – recommended X-ray data are available
- ❑ In general, these data have been recommended from calculations
- ❑ In DDEP, the recommended value is either from calculation or measurements.
- ❑ Depending on the status of the decay dataset and available experimental data – it would be better to consider the recommended value either from calculation or measurements.

Thank you