



O-53: Measurement of the absolute gamma-ray emission intensities from the decay of Nd-147

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Introduction

Neodymium-147 is used as an important indicator of the neutron flux following a nuclear explosion

The 2011 Decay Data Evaluation Project (DDEP) evaluation includes recommended absolute emission intensities for the two main γ-rays at **91.105 (2) keV** and **531.016 (22) keV** with uncertainties of **6.3%** and **7.1%**

Based mainly on two datasets Voinova *et al.*, 1979 and Sainath *et al.*, 1997

The 2009 ENSDF evaluation recommends values with 2.5% and 2.2%

Based only on the measurements of Sainath et al., 1997

The larger uncertainties in the DDEP evaluation stem from inconsistencies in the published data and are unfit for modern purposes

The LNE-LNHB has undertaken new absolute γ-ray emission intensity measurements







An initial feasibility study made it possible to propose a methodology

A dedicated experimental system which could be implemented in a very short time after irradiation of the sample to limit the loss of Nd-147, and allow a measurement on the purified fraction without significant formation of Pm-147

To control the collection phase of the purified fractions eluted at the outlet of the chromatographic column, a static flow divider was added after the column, split on two channels 85% and 15%

The 85% channel went to the collection branch, the 15% branch to the ICPMS to allow live monitoring

Used a liquid chromatography step on a cation exchange column (Luna SCX column) in the presence of a complexing agent (HMB) allowing, as a function of pH and its concentration, to increase the difference in lanthanide affinity towards the support

Tests on high element concentrations to integrate the saturation effect of the substrate and define the appropriate separation conditions using pairs of elements neighbouring Pm in the periodic table, namely Eu / Sm and Nd / Pr

Decided to use two serial analytical columns with diameters of 4.6 mm and 250 mm

These gave collection efficiencies of more than 75%

A flow rate of 1 ml/min gave 16 mL final solution

Source Purification and Separation (3)

$4\pi\beta$ – γ coincidence method

Liquid scintillation (LS) in the β -channel and NaI(TI) for the γ -channel Live-timed anticoincidence instrumentation based on in-house electronics 10 sources were prepared in standard 20 mL vials, each containing 10 mL of UG cocktail plus weighed aliquots of the master solution of ¹⁴⁷Nd Linear fitting was used to obtain the activity, A_0 :

$$\frac{N_{\beta}N_{\gamma}}{N_{c}} = A_{0} \left[1 - \frac{\left(1 - N_{c}/N_{\gamma}\right)}{N_{c}/N_{\gamma}} \varepsilon_{\beta\gamma} \right]$$

 $4\pi\beta-\gamma$ coincidence method: PMT defocussing for the efficiency-extrapolation

$4\pi\beta-\gamma$ coincidence method: homogeneity across the 10 sources

4πβ-γ coincidence method: final resultAbsolute activity 1st sample:And for the 2nd sample: $A_m = 1078.2$ (20) kBq.g⁻¹

$4\pi\gamma$ counting method

A well-type NaI(TI) detector (d = 152 mm and h = 127 mm) Re-entrant hole (d = 21 mm and h = 47.5 mm)

 Absolute activity 1st sample:
 $A_m = 1981$ (13) kBq.g⁻¹

 And for the 2nd sample:
 $A_m = 1075$ (7) kBq.g⁻¹

Confirmation of the result through the two methods

Photon emission intensity measurements (1)

A well calibrated HPGe n-type detector (100cm³)

Series 1: 6 point sources, 20 – 25 mg **Series 2:** 6 point sources, 15 – 31 mg

Photon emission intensity measurements (3)

Source homogeneity

Source impurities

	Source 1 (before separation		Source 2 (after separation)
Impurity	Relative activity	Relative	Detection limit
	(DY/100 DY)	uncertainty (%)	(DY/IUUDY)
¹⁵² Eu	0.04	16	0.011
¹⁵³ Sm	0.12	8	0.010
¹⁴⁸ Pm	0.03	15	0.010
²² Na	0.01	39	0.003

The intensity, *I(E)*, is determined using:

$$I(E) = \frac{N_{net}(E)}{A \cdot t \cdot R_p(E)} \cdot \prod_i C_i$$

where $\prod_i C_i$ is the product of three correction factors: i) decay correction to the reference date

$$C_T = exp\left(-\ln(2)\cdot\frac{t}{T}\right)$$

ii) correction due to ¹⁴⁷Nd decay during the measurement

$$C_{dec} = \frac{\ln(2)\frac{t_m}{T}}{1 - exp\left(-\ln(2) \cdot \frac{t_m}{T}\right)}$$

iii) coincidence correction, obtained using the ETNA code (< 2%)

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Main γ-ray results:

E (keV)	This work	DDEP
91.105	0.2870 (35)	0.284 (18)
120.480	0.003647 (41)	0.00361 (14)
196.640	0.001828 (32)	0.001798 (18)
275.374	0.00781 (14)	0.00775 (11)
319.411	0.01959 (16)	0.01991 (19)
398.155	0.00865 (10)	0.00855 (8)
410.480	0.001065 (14)	0.00137 (6)
439.895	0.01195 (10)	0.01203 (11)
489.24	0.001406 (43)	0.00136 (11)
531.016	0.1311 (13)	0.127 (9)
594.80	0.002429 (26)	0.002653 (36)
685.90	0.00819 (14)	0.00834 (9)

Photon emission intensity measurements (6)

Main γ-ray results:

Photon emission intensity measurements (6)

Weak y-ray results:

E (keV)	This work	DDEP
117.980	DL=1.5 10 ⁻⁵	1.52 (13) 10 ⁻⁴
159.700	DL=1.8 10 ⁻⁵	5.08 (38) 10 ⁻⁵
240.500	DL=1.2 10 ⁻⁵	4.06 (25) 10 ⁻⁴
271.870	1.161 (24) 10 ⁻⁴	1.26 (9) 10 ⁻⁴
357.7	6 (6) 10 ⁻⁵	
366.5	3.4 (30) 10 ⁻⁵	
649.04	DL=9 10 ⁻⁶	4.95 (38) 10 ⁻⁵

Four γ rays not detected – despite having lower detection limit Two new weak γ rays detected

K X-ray results:

E (keV)	This work	DDEP
38.17 (K _{α2})	0.1281 (16)	0.129 (9)
38.73 (K _{α1})	0.2317 (28)	0.235 (15)
43.83 (K _{β1})	0.0708 (9)	0.073 (5)
44.94(Κ _{β2})	0.01880 (23)	0.0187 (13)

Excellent agreement

The absolute emissions intensities for the two main γ rays were with uncertainties of 1.2% and 1.0%, far smaller than the current uncertainties on the evaluated data.

E (keV)	This work	DDEP
91.105	0.2870 (35)	0.284 (18)
531.016	0.1311 (13)	0.127 (9)

The four γ rays at 149.3 keV, 191.0 keV, 541.83 keV and 680.5 keV have measured intensities significantly lower than the evaluated values

The four γ rays at 117.98 keV, 159.7 keV, 240.5 keV and 649.04 keV were not detected (despite lower detection limits

In the DDEP evaluation, six of these γ rays are from a single publication which also quantifies an emission at 80.82 keV; however, in this study, the peak appearing at this energy is identified as the escape of the 91.105 keV γ ray, which leads to doubt in the reliability of the published data.

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Conclusion

The new experimental values obtained during this study should improve the knowledge of the evaluated ¹⁴⁷Nd decay scheme

We are aware that a similar study is currently in progress as a collaboration between the Lawrence Livermore National Laboratory and Texas A&M University

Once the results of this second independent study are published, we hope that a new DDEP evaluation will be undertaken

Thank you for your attention

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