1-PAC: First application of a one-detector gamma-gamma perturbed angular correlation technique for the determination of physical-chemical properties of radioeuropium species

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A new 1-PAC method (perturbed angular correlation measured using one detector only) was developed recently for ^{111}In [1]. In this article the approach is applied to the radiolanthanide ^{154}Eu. The emission used in our measurements on the 123 keV state of ^{154}Gd was the 1274 – 123 keV cascade. The relevant part of the decay scheme is illustrated in Fig.1.

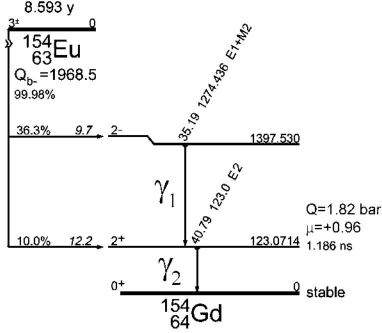

Fig.1. Relevant features of the decay scheme of ^{154}Eu

The time-integrated angular correlation of cascade (TIAC) γ-rays is given by $W(\theta,\infty) = 1+A_{22}G_2(\infty)Q_2P_2(\cos\theta)+\ldots$, [$A_{ii}$-angular correlation coefficients depending on spins and multipolarities of transitions; $P_i(\cos\theta)$ - Legendre polynomials; Q_i-solid angle correction factors; $G_i(\infty)$ -TIAC perturbation factor].

The TIAC $W(\theta,\infty)$ of the ^{154}Eu cascade γ-ray coincidences are given in Fig.2. The solid and dotted lines represent the unperturbed ($G_2(\infty) = 1$) and perturbed angular correlation ($G_2(\infty) = 0.2$), respectively.

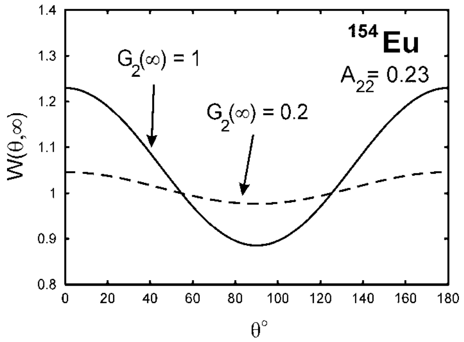

Fig.2. ^{154}Eu time-integrated angular correlation dependencies ($A_{44} \ll A_{22}$)

The γ-spectrum of ^{154}Eu (Fig. 3) consists of "mono peaks" (MP) corresponding to γ- and X-rays full-energy peaks and "summing peaks" (SP) corresponding to the summing energy of these radiations in different combinations. It was shown that the relative probability of recording of cascade γ-rays $R_{\gamma_n+\gamma_m}$ in SP at the individual values of A_{ii}, $G_i(\infty)$ and Q_i is equal to TIAC $W(\theta,\infty)$ [1]:

$$R_{\gamma_n+\gamma_m} = W^{\gamma_n,\gamma_m}_{A_{ii},G_i,Q_i}(\theta = 0^\circ,\infty)\cdot \qquad (1)$$

Similar to ^{111}In, for ^{154}Eu $R_{\gamma_n+\gamma_m}$ can be obtained as:

$$R_{\gamma_1+\gamma_2} = N_{K_{\alpha,\beta}+\gamma_1}\cdot\frac{S_{\gamma_1+\gamma_2}\cdot S_{K_{\alpha,\beta}}}{S_{\gamma_2}\cdot S_{\gamma_1+K_{\alpha,\beta}}}, \qquad (2)$$

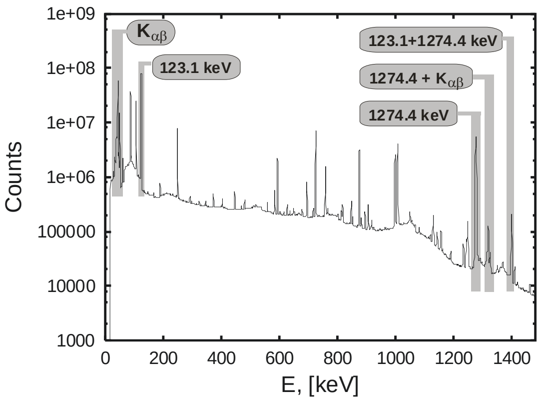

Fig.3. The γ-spectrum of ^{154}Eu obtained using an HPGe-detector

with $S_{\gamma n}$ – MP area, $S_{\gamma n+\gamma m}$ – SP area. For ^{154}Eu, the normalisation coefficient is:

$$N_{K_{\alpha,\beta}+\gamma 1} = \frac{y_{e(K)}(\gamma_2)}{\sum_i y_{e(K)}(\gamma_i)} = 0.9241, \qquad (3)$$

with $y_{e(K)}(\gamma_i)$ - the yields of electrons in the conversion process on the K-shell, corresponding to γ_i [2].

1.20 GBq of ^{154}Eu have been produced by a 737 h neutron irradiation of 1 mg europium oxide (99.71% of ^{153}Eu) at the BER II reactor (HMI, Berlin) at a flux of $2\cdot10^{14}$ n/cm^2 s. The ratio of ^{155}Eu/^{154}Eu activities was obtained to be 0.39. Due to the contribution of X-rays of ^{155}Eu the overall experimental normalisation coefficient is 0.6861.

1-PAC measurements were performed using polyethylene vials ("Eppendorf") of 2 ml volume. The activity of the samples was 50 kBq. The volume of each sample was 0.5 ml. The measurements were carried out with a coaxial HPGe detector of 250 cm^3 volume, 64.8% relative efficiency (1332 keV). The source-detector distance was 42 mm from the detector surface. The obtained $R_{\gamma_n+\gamma_m}$ -values for different solutions and compounds of Eu(III) are presented in Tab.1:

Tab.1: $R_{\gamma_n+\gamma_m}$ -values of ^{154}Eu for different solutions and compounds

Compounds	$R_{\gamma 1+\gamma 2}$	**σ**
1M $HClO_4$	1.1945	0.0043
0.01M $HClO_4$	1.1946	0.0043
Eu(III)-DTPA	1.1519	0.0040
$Eu(OH)_3$(c)	1.1176	0.0041
EuF_3(c)	1.0964	0.0040

$R_{\gamma_n+\gamma_m}$ –values, reflecting the different physical-chemical status of Eu(III), are maximum for Eu^{3+}-cationic forms and decrease due to complex or solid phase formations. It is thus shown that this approach allows to study the physical-chemical properties of ^{154}Eu.

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