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INVESTIGATION OF THE DECAY OF Eu^{147} AND Eu^{148} BY THE SUM COINCIDENCE METHOD

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The $\gamma\gamma$-coincidence technique in conjunction with a scintillation spectrometer was used to investigate the decay of long-lived europium isotopes produced as a result of disintegration of tantalum by 660 MeV protons. A search was made for a 900 keV level which may be excited in the decay of Eu^{147}. No experimental proof of the existence of the level has been obtained. The well known two-step transitions in Eu^{148} decay are confirmed. A procedure for reliable identification of levels in the Hoogenboom method[6] is proposed in the presence of cascade transitions from higher levels.

INTRODUCTION

THE decay schemes of the neutron-deficient isotopes Eu^{147} and Eu^{148} were investigated by the coincidence method in several works[1-4]. However, the existence of the 900-keV level in the decay scheme of Eu^{147} is subject to contradictory information. This level was introduced by Vizi et al[1] and was not observed in [2,3]. However, a decay scheme with the 900-keV level is used for Eu^{147} in Soviet investigations. The methods used in [1] to prepare and investigate the Eu^{147} differ from those used in [2,3] and, in order to clarify the reasons for the differences in the experimental results on Eu^{147}, we investigated its decay by producing this isotope by the same method as in [1] and by using the same sum coincidence procedure.

An investigation of the europium fraction at our disposal with a $\pi\sqrt{2}$ beta spectrometer[5] using the internal-conversion electrons has shown that the source contained a small Gd impurity in addition to the $\mathrm{Eu}^{146-149}$ isotopes. A complex conversion line decay with a half-life ~ 5 days and attributed to Eu^{145} and Eu^{146} was identified with the β spectrometer in the 900 keV γ-quantum energy region. The isotopes Eu^{145}, Eu^{146}, Eu^{149}, and Gd introduced no noticeable errors in the experimental results obtained by the coincidence method, in view of the predominant Eu^{147} and Eu^{148} content and in view of the features of the investigation procedure employed. The Eu^{148} impurity at the start of the measurement was approximately 3.5 times larger than in [1].

The coincidences were investigated with a scintillation spectrometer with NaI(Tl) measuring 40×40 mm and with resolution of 10 and 12% relative to Cs^{137}. The coincidence circuit had a resolution time 2.5×10^{-7} sec at 100% registration efficiency for coincidences of pulses with an amplitude ratio of 12. The crystals were placed at a 180° angle, with a 4 mm lead shield between them to eliminate the backward scattering from crystal to crystal. The distance between crystals was set at 25 or 12 mm, depending on the coincidence rate. An AI-100-channel analyzer was used for pulse-height analysis.

INVESTIGATION OF Eu^{147}

The sum coincidence method[6] used by Vizi et al[1] is applicable, as is well known, to investigations of two-step γ transitions from a higher excited level of the nucleus. As shown above[7], when the window is set below the highest excitation level from which cascade transitions are possible, the sum-coincidence pulse spectrum will contain, in addition to the expected cascades from the investigated level, also distorted cascades from higher levels. The measures adopted to eliminate this effect are not mentioned in [1].

The sum-coincidence pulse spectrum obtained by the Hoogenboom method[6] with the window set at 800 keV is similar to the corresponding spectrum of [1]. The obtained peak pairs 120—680 and 198—602 keV confirm the 800-keV level. The pulse spectrum with the 900 keV window is also similar to the corresponding spectrum of [1] with clearly distinguished peak pairs 120—780 and 198—702 keV, which are regarded in [1] as two-step cascades from the 900 keV level. With this window, peaks from Eu^{148} appear in our spectra with comparable intensity, but they do not disturb the identification and determination of the areas of 120 and 198 keV peaks of Eu^{147}, an important factor in the subsequent analysis. The pulse spectrum obtained with the window set at 1080 keV is shown in Fig. 1. The peak pair 120—957 and 198—880 keV characterizes two-step γ transitions with corresponding energies from the 1080 keV level. The 415 and 610 keV peaks and the double 530 keV peak are due to Eu^{148} cascades.

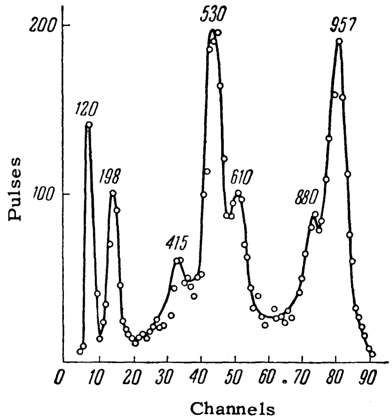

FIG. 1. Spectrum of some coincidence pulses by the Hoogenboom method[6]. The window is set at 1080 keV with a width of 90 keV.

It is clear that if the window is moved in the vicinity of a certain level (from which two-step γ transitions are possible), the counting rate at the peaks of the coincidence spectrum should vary and exhibit a maximum when the window is set exactly to the energy level. Auxiliary measurements, made with 600—800 keV Cs^{134} cascades, have shown that in the sum-coincidence pulse spectrum the dependence of the area under the 600 (800) keV peak on the position E_0 of the window has the same appearance as the single-crystal spectrum of γ-line pulses of 800 (600) keV, provided the width of the window is not more than 2% of E_0.

It is obvious that if the window is moved in the 900-keV region, the coincidence spectra of Eu^{147} should display an increase in the intensity of the 120 and 198 keV peaks on passing through the 900-keV level, if the latter exists.

Figure 2 shows the areas of the 198 keV peak (S_{198}) and of the 120 keV peak (S_{120}) vs. the window position. The statistical error is shown for some points and does not exceed the dimensions of the points for the points with $E_0 > 1.15$ MeV. As can be seen, the areas of these peaks change noticeably when the window passes through the energy level from which two-step transitions with

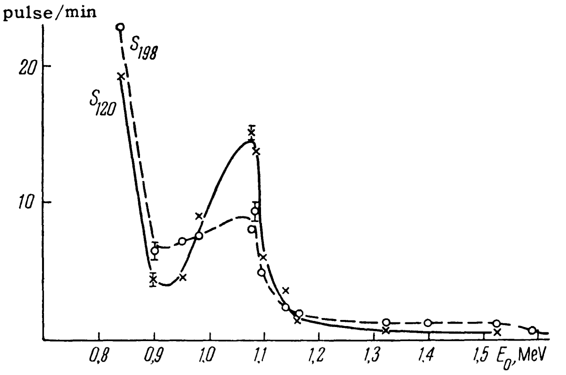

FIG. 2. Area under the 120 keV peak (S_{120}) and 198 keV peak (S_{198}) of Eu^{147} against the position E_0 of the window by the Hoogenboom method. Window width 90 keV.

participation of 198 or 120 keV γ quanta are possible. Thus, the areas of both the 198-keV and the 120 keV peaks decrease sharply on passing the 800-keV level, and again increase as E_0 approaches the 1080-keV level.

In the region $E_0 \sim 900$ keV, the expected change in the areas of the 198 and 120 keV peaks is not observed. The absence of a specific increase in the intensity of the coincidences in this region indicates that the observed 120 and 198 keV peaks observed in the sum-coincidence spectrum with a window at $E_0 = 900$ keV are due to the cascades from the level 1080 keV exclusively.

With an aim at searching for the 900-keV level, we also plotted the spectrum (Fig. 3) of the sum of the amplitudes of the coinciding pulses by a method proposed in [8]. In this method, each two-step cascade of γ rays with energies E_1 and E_2 in the

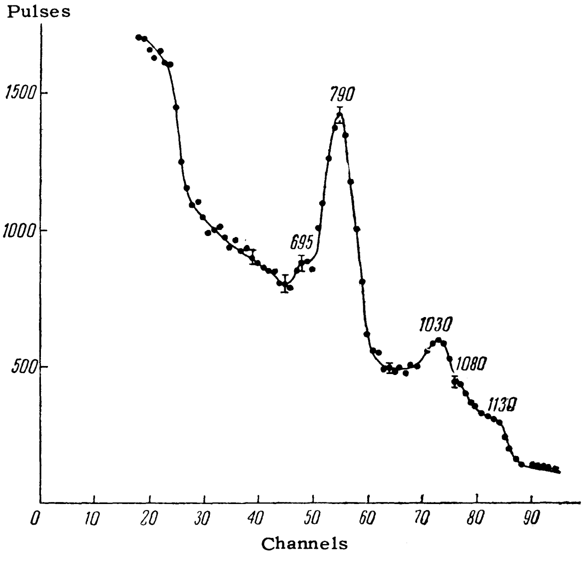

FIG. 3. Spectrum of summary amplitudes of coinciding pulses by the method of[8]. 790 and 1080 keV peaks— Eu^{147}. The 695, 1030, and 1170 keV peaks are those of Eu^{148}.

"sum" spectrum corresponds to a "photopeak" with energy $E_1 + E_2$ and a certain "Compton" pulse distribution.

In Fig. 3 the 790 keV peak corresponds to the 608—198 keV and 680—120 keV cascades; the convex part in the 1080 keV region is due to the 880—198 and 957—120 keV cascades of E^{147}.

The 695, 1030, and 1170 keV peaks are due to two-step cascades of Eu^{148}. In the 900 keV region (700—198 and 780—120 keV cascades according to [1]), no peak was observed within the experimental accuracy limits.

On the basis of the performed measurements we assume that the appearance of the 120 and 200 keV peaks and the complementary 780 and 700 keV peaks obtained by Vizi et al[1] with the window set at 900 keV must be interpreted as due to the influence of the 957—120 and 880—198 keV cascades from the 1080 keV level, and not as proof of the existence of a 900-keV level with 780—120 and 700—198 keV cascades.

Schwerdtfeger et al[3] have indicated that an investigation of the decay of Eu^{147} in the 1400-keV region discloses a possible energy level observable in the coincidence spectrum. In our investigations of Eu^{147} by the Hoogenboom method[6], with the window set above the 1080 keV level, peaks are observed in the pulse spectrum at 120 and 200 keV, which may possibly be regarded as a proof of the existence of the coincidences between the 120 and 198 keV γ rays and γ rays with energies higher than 957 keV. The dependence of the area under the 198 keV peak on the position E_0 of the window (Fig. 2) displays a behavior which is characteristic of a level in the vicinity of 1500 keV. The area under the 120-keV peak decreases smoothly and does not even permit a tentative conclusion concerning the levels above 1080 keV. From the ratio of the areas under the 120 and 198 keV peaks we can conclude that if levels above 1080 keV are actually excited in the decay of Eu^{147} to Sm^{147}, then two-step transitions from these levels proceed more intensely via the 198 keV level, and not via the 120 keV level. The question of the levels of Sm^{147} above 1080 keV calls for a special additional study.

INVESTIGATION OF Eu^{148}

As already noted above, the compound at our disposal contained essentially Eu^{147} and Eu^{148}. Thus, Fig. 3, obtained by the method proposed in [8], shows several peaks due to the Eu^{148} cascades. The 695 keV peak is due to coincidences of the 630 keV γ line and the 47 keV x-rays, and corresponds to their total energy. The 1030 keV peak is due to 415—630 keV cascade; the 1170 keV peak is due to the 630—550 keV cascade.

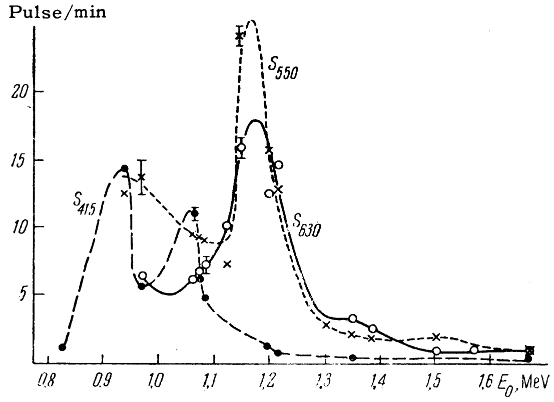

FIG. 4. Dependence of the areas under the 415 (S_{415}), 550 (S_{550}) and 630 keV (S_{630}) peaks of Eu^{148} on the position of the window, E_0, by the Hoogenboom method. Window width 90 keV.

Figure 1, obtained by the Hoogenboom method [6], shows clearly the 415, 530, and 610 keV peaks, characterizing the 415—630, 630—550 keV cascades of Eu^{148}. Analogous spectra plotted up to $E_0 \sim 1.7$ MeV enable us to plot the area S under the 415, 550, 630, and 725 keV peaks against the window position E_0.

This dependence of these areas, except 725 keV, is plotted in Fig. 4. The dependence of S_{550} on E_0 shows rises in the regions of 900, 1180, and 1500 keV, indicating 415—550, 630—550, and 1020—550 keV cascades. The 415—630, 630—550, and 730—630 keV cascades are determined by the course of the S_{630} curve. Analogously, the 730—550 and 730—630 keV double coincidences are determined from the course of S_{725} curve.

The results obtained agree with those obtained in the investigation of Eu^{148} by the usual coincidence method[9-10].

In conclusion, the authors take the opportunity to thank Prof. A. Fry and the authors of [8] for acquainting them with their paper prior to publication.

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