On gamma-rays in the population of the spontaneously fissioning isomer in the reaction ^{241}Am (n,γ) ^{242m}Am

G. V. Val'skii, V. L. Varentsov, G. A. Petrov, Yu. S. Pleva, and Ya. M. Otchik
B. P. Konstantinov Institute of Nuclear Physics, USSR Academy of Sciences

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A large number of theoretical and experimental papers are devoted to the study of short-lived spontaneously fissioning isomers of the actinide nuclei (Ref. 1, for instance), however, there have been no reliable data up to now on the quantum characteristics of the spontaneously fissioning states and the radiation properties during their population in nuclear reactions. At the same time this information is essential to the clarification of the nature of this interesting phenomenon in nuclear physics, and for a direct verification of the now extensively-used hypothesis about the two-humped fission barrier.[2] Within the framework of this hypothesis the isomeric state is treated as a quasistationary state with inordinately large deformation.

We report in this work the first results of an investigation of the properties of gamma-radiation accompanying the population of the spontaneously fissioning state ^{242m}Am in the thermal neutron capture reaction.

The spontaneously fissioning isomer ^{242m}Am with a half-life of about 14 msec has been investigated thoroughly in various nuclear reactions. It is the sole reliable example of the formation of a spontaneously fissioning isomer in reactions with thermal neutrons.[3] On the other hand, the thermal neutron capture reaction provide a useful means for studying the population mechanism of spontaneously fissioning states since only gamma-rays or conversion electron radiation is possible because of energy considerations.

The detection of these radiations is a formidable experimental task in the case under consideration. Indeed, the total radiation capture cross section for thermal neutrons in this reaction is around 10^3 b, the "instantaneous" fission section is ~ 3 b, and the cross section for the formation of an isomeric state with half-life ~ 14 msec is just $\sim 6\times 10^{-4}$ b.[3] The standard coincidence method is of low efficiency in this case because of the long half-life of the isomeric state. Meanwhile, there are no current data on the shape of the gamma spectrum in the hard region.

Consequently, we developed a special measurement method, described earlier in Ref. 4. Briefly, it consists of the following. A ring target, rotating at 3000 rpm, is exposed continuously to a narrow beam of thermal neutrons. The isomers ^{242m}Am being formed during the exposure move out of the beam during rotation and spontaneous fissions are recorded with $\sim 25\%$ efficiency by a ring device consisting of 23 spark counters. The gamma rays, emitted almost instantaneously after the capture of the neutrons, are recorded with $\sim 13\%$ efficiency by a NaI(Tl) crystal scintillation spectrometer. The gamma-ray spectra are recorded successively in theappropriate zone of the buffer storage of the recording system in a ~ 0.67-msec time interval during each rotation of the target. If none of the spark counters is activated during a rotation, the spectra are alternately replaced by new spectra; if some of the counters are activated, all the spectra stored during the last rotation of the target and the code number of the spark counter are transmitted to the electronic computer for processing. The spectrum containing the desired "effect" is recorded separately by using the electronic computer during such an event, while all the remaining spectra are used to determine the background.

Such a method permitted a highly efficient and near-simultanous measurement of the "effect" and the "background." This is essential since the desired gamma-ray spectrum was obtained as a difference between large numbers during the population of the isomeric state. "Null" experiments were performed to validate the apparatus operation and the reliability of subtracting the background spectrum. In one of these, random pulses from an external source were used in place of the recorded pulses produced by spontaneous fission events. Another kind of "null" experiment was the known-to-be-false sampling of a gamma-spectrum "effect" from the buffer storage during activation of the spark counters, and was conducted simultaneously with the main experiment. All the tests affirmed the validity of system operation and the correctness of background subtraction even in the case of sharp peaks present in the spectrum.

The net measurement time was ~ 4 months, where $\sim 10^5$ spontaneous fission events were stored. The key results are shown in the Fig. 1: a) the gamma-ray spectrum stored in coincidences with the lagging fissions (before subtracting the background); b) the difference spectrum (after subtracting the background); c) the result of the "null" test with the external source. A gamma-ray energy range between 0.4 and 3.8 MeV was studied in this experiment. Because at this stage of the research the problem of obtaining general information about the nature of the gamma-ray spectrum was addressed (primarily the verification of its existence) the amplitude analysis was conducted on 18 channels with a channel width of 0.2 MeV.

To verify the statistical significance of the deviation observed in the difference spectrum at $E_\gamma = 2.2$ MeV, the data were processed mathematically for three hypotheses on the form of the gamma-ray difference spectrum: 1) $y=0$; 2) $y=ae^{-bx}$; 3) $y=f(x)$, where $f(x)$ is an approximation of the response function of the scintillation

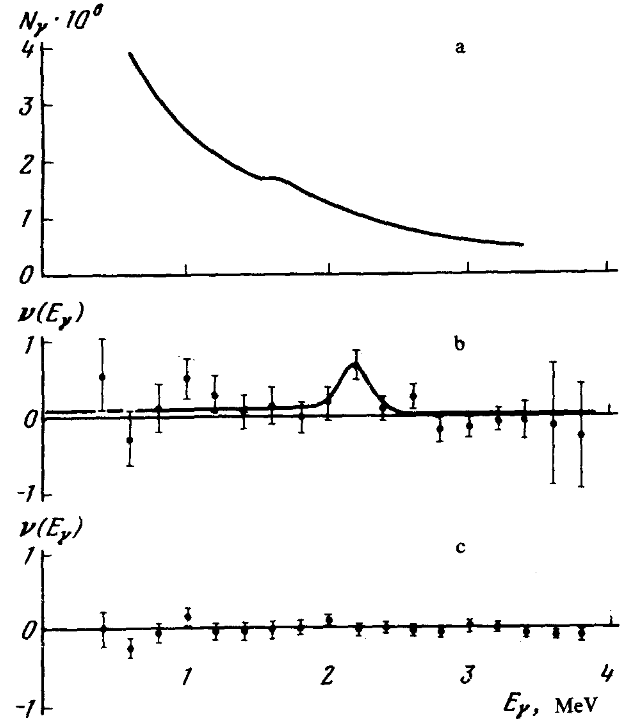

FIG. 1. Experimental results: *a*—Spectrum of gamma-rays obtained in coincidences with lagging fissions (before subtracting the background); peak associated with the activation Al is seen; *b*—difference spectrum (after subtracting the back-ground); *c*—result of a null test with an external source.

spectrometer for monochromatic gamma-lines, shown by the solid curve in figure (*b*). The confidence levels of the hypotheses turned out to be 0.10, 0.85, and 0.98, respectively. Within the framework of the last hypothesis, the energy corresponding to the maximum peak $E_\gamma = 2.2 \pm 0.08$ MeV and the photon yield at this energy per isomer being formed $Y = 1.3 \pm 0.4$ were obtained from the values of the parameters to fit the curve $f(x)$ to the experimental data. However, since even the "null" hypothesis cannot be repudiated reliably (a 10% confidence level), additional measurements involving refined apparatus are required for a final selection of an appropriate hypothesis.

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