ALPHA PARTICLE SPECTRA IN THE DECAY OF EXCITED STATES OF Sm^{148} WITH SPINS 3^- AND 4^-

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The investigation of the spectra of α particles in the (n, α) reaction yields new data on the structure of highly excited states of nuclei and new characteristics of α decay. The most interesting is, apparently, the study of the probability, characterized by the reduced widths, of α-particle production on the surface of the nucleus, for different states of the compound nucleus.

Investigations of this kind are difficult and were performed heretofore with thermal neutrons [1-5]. However, the interpretation of such data is frequently ambiguous because of the uncertainty of the quantum characteristics of the excited states. Resonant neutrons were used to investigate only the total α widths of the reaction [6,7].

We report in this paper the first results of the measurement of the α-particle spectra in individual resonances.

Measurement procedure and results. The spectra of the α particles in the resonances of the $Sm^{147}(n, \alpha)Nd^{144}$ reaction were investigated with the IBR pulsed reactor. The neutron spectrometry was by the time-of-flight method. The spectra of the α particles were measured with a double ionization chamber with a grid, with 200 keV resolution (for $E_\alpha = 4.2$ MeV). The pulses from the chamber were analyzed with a two-dimensional magnetic-tape analyzer in the time-amplitude mode. The target was a layer of oxide enriched with the isotope Sm^{147} (300 $\mu g/cm^2$) with total area 1200 cm^2.

The measurements yielded the spectra of the α particles in the resonances with $E_0 = 3.4$ and 18.3 eV, with spins and parities $J^\pi = 3^-$ and 4^- [8] respectively (see the figure).

Discussion of results. Upon capture of neutrons with zero orbital angular momentum by the Sm^{147} nuclei, excited states of the Sm^{148} nuclei are produced, with $J^\pi = 3^-$ and 4^-. Inasmuch as the $4^- \to 0^+$ α transitions are forbidden, the presence of an α transition in the ground state of the daughter nucleus Nd^{144} (the characteristics of the Nd^{144} levels are listed in the table) at the 3.4-eV resonance and its absence from the 18.3-eV resonance con firms the identification of the resonances by spins, given in [8], but contradicts the identification of Cheifetz et al. [2], which is based on indirect considerations.

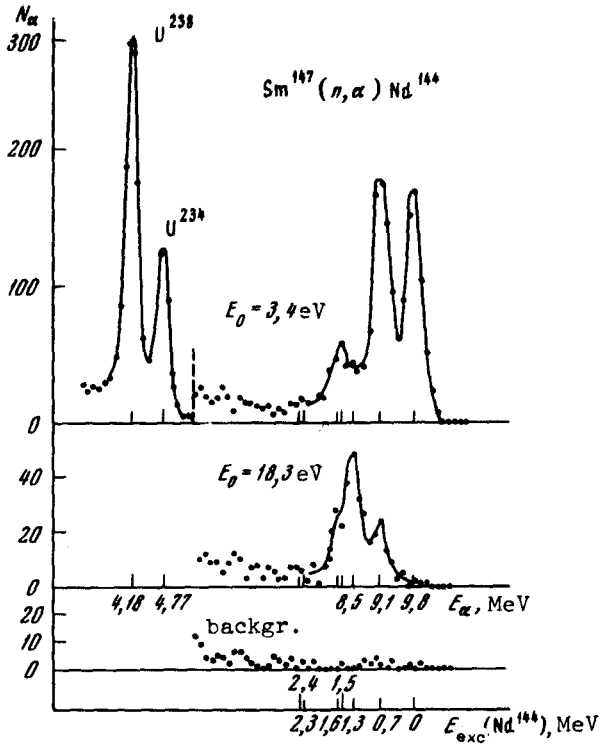
It is interesting to note that in the spectra measured by us the α transitions to the lowest states are not predominant, as is the case with the traditional α decays for even-even nuclei.

Comparison of the intensities of the α transitions to individual states yielded the values of the reduced partial widths $\delta^2_{0i} = 2\pi(\Gamma_{\alpha i}/P_i)$, where P_i is the penetrability of the nuclear barrier for an α particle with energy and orbital angular momentum corresponding to the given transition [9]. To obtain the absolute values of $\Gamma_{\alpha i}$ we used the total α widths $\Gamma_\alpha = \sum_i \Gamma_{\alpha i}$ measured in [6].

Characteristic of levels of the daughter nucleus and reduced probabilities of α transitions to these levels in the $Sm^{147}(n, \alpha)Nd^{144}$ reaction

E_{exc}, MeV	J^π	E_0 = 3.4 eV, $J^\pi = 3^-$			E_0 = 18.3 eV, $J^\pi = 4^-$		
		N_α	$\Gamma_{\alpha i}$, μeV*	δ^2_{0i}, eV**	N_α	$\Gamma_{\alpha i}$, μeV*	δ^2_{0i}, eV**
0	0^+	627	0.70 ± 0.03	1.6 ± 0.1	-	-	-
0.696	2^+	716	0.80 ± 0.03	5.2 ± 0.2	78	0.05 ± 0.02	1.0 ± 0.4
1.31	4^+	98	$0.11^{+0.05}_{-0.08}$	$7.2^{+3.3}_{-5.2}$	170	0.11 ± 0.02	7.2 ± 1.2
1.50	(3)	197	0.22 ± 0.05	12 ± 3	62	0.04 ± 0.02	3.2 ± 1.6
1.56	2^+						
2.29	4^+	~35	0.04 ± 0.03	100 ± 80	~10	0.007±0.006	26 ± 22
2.37	2^+						

* The summary widths are given for the transitions to the levels 1.50 - 1.56 and 2.29 - 2.37 MeV, which are not energy-resolved.
** Average reduced widths are indicated for unresolved transitions.
The errors indicated in the table do not include normalization errors.



Energy spectra of α particles in the decay of Sm^{148} excited states with spins and parities $J^\pi = 3^-$ and 4^- (neutron resonances with E_0 = 3.4 and 18.3 eV, respectively). The lower curve characterizes the background messured in the interval between the indicated resonances. Under the energy scale for the α particles are marked the positions of the energy levels of the daughter nucleus Nd^{144} to which the α decay takes place.

Analyzing the values of the reduced widths of the reaction (see the table), we can note the following singularities:

1. The values of δ^2_{0i} fluctuate in a wide range and independently in each resonance. The latter is connected with the difference in the nature of the initial excited states, and indicates that the assumption customarily used in the analysis of α spectra in capture of thermal neutrons, namely that the values of δ^2_{0i} are the same for different excited states, is incorrect.

2. The values of δ^2_{0i} for α transitions to excited states with $E_{exc} < 1.5$ MeV are much smaller than the mean distance between the levels of the compound nucleus, to which they should equal in the mean according to the statistical theory ($\delta^2_{stat} = D = 14$ eV).

We note that in the Sm^{149}(n, α) reaction on thermal neutrons [5] it was observed that δ^2_{0i} increases (up to values $\sim\delta^2_{stat} = 6$ eV) for α transitions to the levels of the daughter nucleus lying above the pairing energy of the last neutrons.

It is possible that these facts are connected with the effect of pair correlations of the neutrons in excess of the closed shell N = 82. After all, α decay to the ground or excited state with $E_{exc} < E_{pair}$ requires that there be formed in the compound nucleus not only an α particle, but also paired neutrons. This should lead to a decrease in the value of δ^2_{0i} for transitions to states with paired neutrons.

It can be noted that the effect of paired correlations of the neutrons should be manifest also in a decrease of the experimental values of $\bar{\Gamma}_\alpha$ compared with those calculated from the statistical theory, as was observed for the isotopes Sm^{147} and Sm^{149} [10].

For higher resonances, the statistics of the counts turned out to be insufficient for analysis of the α-particle spectra, but the presence of an α transition to the ground state at the 27.1-eV resonance indicates that the spin of this resonance is 3^-.

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