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In this report the first results of our investigations of the α-decay of the highly excited nuclear states formed in the resonance neutron capture are given.

The (n , α) reaction gives to experimentators disposal a specific possibility allowing a) to investigate the α-decay from a large number of discrete levels (for which the average level spacings, parities and sometimes spins are known), b) to extend noticeably the region of α-decaying nuclei, because the neutron capture increases the α-particle emission probability by many orders of magnitude (for Nd by more th. 30 orders).

It is interesting to compare the α-particle widths $\Gamma\alpha$ averaged over a large number of resonances, with the statistical theory predictions, and also to study the α-particle widths distribution and to investigate the correlations of the values $\Gamma\alpha$ with other resonance parameters (spins, neutron widths and so on).

The measurements were made on pulsed reactor IBR with a microtron as an injector. The time-of-flight method at 100 and 30 ns/m resolution was used.

A gaseous scintillation xenon-filled counter with a multilayer target served as the α-particle detector /1/. Targets of excited of natural Sm, Nd and isotopically enriched ^{143}Nd (4-8 mg/cm^2 thick) on Al backing were used. Total target weight was 20-30 g. The α-particles, the backround and the γ rays from (n , γ) reaction (detected by a separate γ detector) were recorded simultaneously by 1024 - channel time analysers.

The neutron energy dependence of the α-particle counting rate (lower curve) and of the γ-ray counting rate (upper curve) from measurements with samarium[2] and ^{143}Nd are shown in Fig. 1 and 2, respectively. The lack of maxima on (n , α) curves at energies corresponding to the strong resonances of the (n , γ) reaction (^{129}Xe $E_0 = 9.4$ eV, ^{131}Xe – 14 eV, ^{152}Sm – 8 eV) allows us inspect constantly the insensitivity of the α-particle detector to γ rays. Another evidence of the same fact was obtained by an additional measurement with samarium target covered by 60 μ Al foil, which completely absorbed the α particles from Sm (n , α) reaction. This confirms also that the detected particles are indeed α-particles.

The area ratio for corresponding resonances in (n , α) and (n , γ) curves is proportional to the partial widths ratio $\Gamma\alpha / \Gamma\gamma$. To find the absolute values of $\Gamma\alpha$ the (n , α)[3,4] and (n , γ)[5] cross sections for ^{149}Sm and ^{143}Nd at thermal neutron energies were used.

On examining (Fig. 1 and 2) one can see that some resonances clearly revealed in the (n , γ) curves are very weak or absent in the (n , α) curves. Sometimes this circumstance may be connected with a spin value of the resonance. When neutrons with zero orbital momentum are captured by the nuclei studied (^{149}Sm , ^{147}Sm, ^{145}Nd, ^{143}Nd) compound states with $J^{\pi} = 4^-$ and 3^- are formed. The ground states of the daughter nuclei ^{144}Nd, ^{146}Nd, ^{140}Ce, ^{142}Ce have $I = 0^+$ while the first excited states have $I = 2^+$.

Thus, for the compound nucleus levels $J^{\pi} = 4^-$, α-decay is possible only to the excited states, whereas for $J^{\pi} = 3^-$ levels transitions both to the ground and excited states are allowed. Since the probability of the α-particle penetration through the Coulomb barrier falls off quickly with decreasing α-particle energy the widths $\Gamma\alpha$ for the 3^--levels are larger than those for 4^--levels. This is displaied especially clearly in the case of ^{143}Nd (α-decay schema is given on Fig. 2), because the first excited state of the magic nucleus ^{140}Ce is very high (L.6 MeV).

The values of $\Gamma\alpha$ obtained for ^{143}Nd are presented in table 1, the same for Sm isotopes are given in our preprint[2]. It is interesting to notice, that the α-particle widths of the three lowest ^{149}Sm resonances with $J^{\pi} = 4^-$ fluctuate weakly. In the same time the

α -particle widths for ^{147}Sm resonances at $E_n = 3.4$ eV and 18.3 eV, and with $J^{\pi} = 3^-$ and 4^-, respectively, differ by an order of magnitude.

As the calculated for ^{148}Nd ratio of the probabilities for α transitions $3^- \rightarrow 0^+$ and $4^- \rightarrow 2^+$ is about 100, we considered it justified to assign J^{π} to all ^{148}Nd resonances observed in our measurement (see table 1).

However, such identification is not always quite safe. Let us suppose that the distribution of $\Gamma\alpha$ is the Porter-Thomas one with $\nu = 1$. Then the $\Gamma\alpha$ distributions for $J^{\pi} = 3^-$ and 4^- states will partly overlap. In the same time our spin identification for Sm is in agreement with the results obtained by other methods. In order to show that the distribution of the $\Gamma\alpha$ is really the Porter-Thomas one with $\nu = 1$ it is necessary to investigate more resonances.

In table 2 the experimental and calculated average widths for the α transitions from levels of the same spin and (in brackets) the number of averaged resonances are given. The theoretical $\bar{\Gamma}\alpha$ were calculated using expression $\bar{\Gamma}\alpha = D/2\pi \times \sum_{\ell} T_{\ell}$, where D is average level spacing for states near the capturing states of the same spin and parity, and T_{ℓ} is the transmission probability for an ℓ -wave α particle /6/.

Let us note the good agreement of the experimental data with the theoretical values for ^{143}Nd and ^{149}Sm, but somewhat poor agreement for ^{147}Sm and ^{145}Nd. Errors in the experimental values of $\bar{\Gamma}\alpha$ many arise from omission of weak resonances, from averaging over small number of resonances and from calibration errors. However, these errors can not change the magnitude of $\bar{\Gamma}\alpha$ more than trice.

In the near future the (n, α) experiments with isotopically enriched Sm and Nd will be carried out. Investigation of the (n, α) reactions in other atomic number regions is also planed.

References

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Table 1

Alpha-particle widths of the ^{143}Nd resonances

E_0 eV	-6	55.5	127	136	157	180	187	410
J^π	3^-[5]	4^-	3^-[5]	3^-	4^-	3^-	4^-	3^-
$\Gamma_\alpha \times 10^5$ eV	0.59 [3]	≤ 0.1	3.0	13.0	≤ 0.1	1.0	≤ 0.2	4.0
$\Delta\Gamma_\alpha \times 10^5$ eV	$\pm$ 0.12		$\pm$ 0.6	$\pm$ 2.6		$\pm$ 0.5		$\pm$ 1.2

Table 2

Average α-particle widths for Nd and Sm isotopes

J^π		3^-			4^-
Isotop		^{143}Nd	^{145}Nd	^{147}Sm	^{149}Sm
$\Gamma_\alpha \times 10^7$ eV	exper	430 (5)	8 (3)	19 (5)	0.74 (3)
	theor	350	2.8	61	0.83

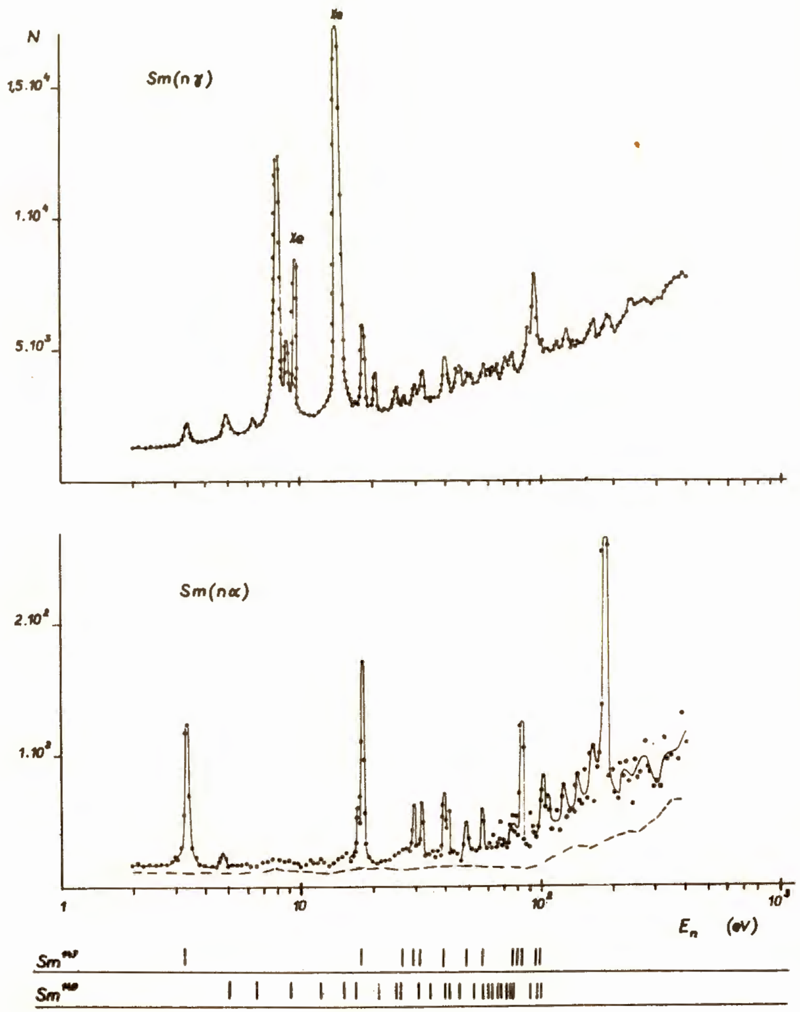

Fig. 1. Recorded number of α particles (lower curve) and γ-quanta (upper curve) for Sm plotted against the neutron energy. The resonance energies for ^{149}Sm and ^{147}Sm available from total neutron cross section measurements (5) are given below the spectra.

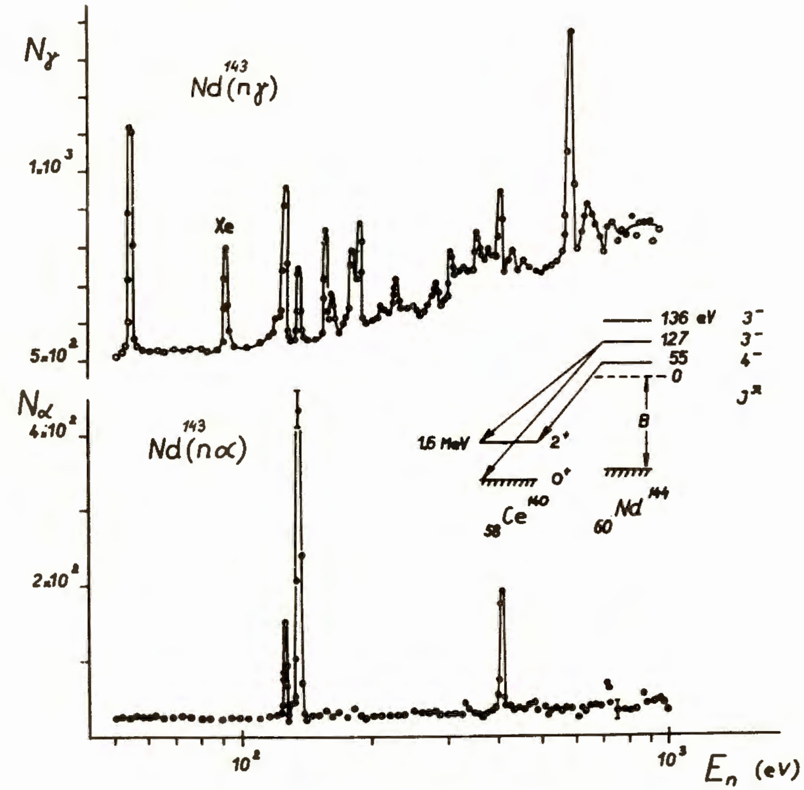

Fig. 2. Recorded number of α particles (lower curve) and γ-quanta (upper curve) for enriched ^{143}Nd plotted against the neutron energy. Alpha-decay mode from excited states of ^{144}Nd is given.