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THE QUATERNARY FISSION AS A VIRTUAL PROCESS

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In experimental papers [1, 2] the yields, angular and energy distributions of the pairs of light third and fourth particles formed with the highest probability, such as α-particles pair (α_1, α_2), were obtained for the spontaneous quaternary fission of the nucleus ^{252}Cf. Using the theoretical concepts [3-5] of ternary and quaternary fission as virtual processes [6], we consider spontaneous quaternary fission from the ground states of even-even actinides [1,2] with the sequential emission of two α-particles from the virtual states of nuclei A and $(A-4)$ and the subsequent binary fission of the residual fissile nucleus $(A-8)$ into light and heavy fission fragments. These α-particles, in contrast to the α-particles that fly out in the sub-barrier α-decay of the studied nuclei A and $(A-4)$, when the energies $Q^A_{\alpha_1}$ and $Q^{(A-4)}_{\alpha_2}$ of this decays are close to 6 MeV, are long-range, since their asymptotic kinetic energies $T_{\alpha_1} \approx 16$ MeV and $T_{\alpha_2} \approx 13$ MeV, are markedly larger than energy values $Q^A_{\alpha_1}$ and $Q^{(A-4)}_{\alpha_2}$. Using the formula [4] for the width $\Gamma^A_{\alpha_1\alpha_2 f}$ of the virtual quaternary fission of nucleus A, formulae for the widths $\Gamma^A_{\alpha_1}(T_{\alpha_1})$ and $\Gamma^{(A-4)}_{\alpha_2}(T_{\alpha_2})$ for α-decays of nuclei A and $(A-4)$ are constructed:
$\Gamma^A_{\alpha_1}(T_{\alpha_1}) = 2\pi W_{\alpha_1}(T_{\alpha_1})(Q_{\alpha_1} - T_{\alpha_1})^2; \Gamma^{(A-4)}_{\alpha_2}(T_{\alpha_2}) = 2\pi W_{\alpha_2}(T_{\alpha_2})(Q_{\alpha_2} - T_{\alpha_2})^2;$
where $W_{\alpha_1}(T_{\alpha_1})$ and $W_{\alpha_2}(T_{\alpha_2})$ are the energy distributions of the first and second α-particles, normalized by the ratio of the widths of these α-particles emission to the width of the binary fission of the nuclei A and $(A-4)$. The widths $\Gamma^A_{\alpha_1}$ and $\Gamma^{A-4}_{\alpha_2}$ take into account the fact that the emitting α-particles are formed in such configurations of the fissile nuclei A and $(A-4)$ that occur during their deformation motion from the ground states through the internal and external fission barriers and reach a pear-shaped forms corresponding to the appearance of two deformed fission prefragments connected by a neck. If we consider the ratio $\Gamma^A_{\alpha_1}/\Gamma^{(A-4)}_{\alpha_2} = \sqrt{T_{\alpha_1}}P_1(T_{\alpha_1})/\sqrt{T_{\alpha_2}}P_2(T_{\alpha_2})$ and take into account the fact that the probabilities of formation of the α_1 and α_2 particles are close to each other, and the radii of the neck of the nucleus r_A before the emission of α_1-particle does not differ much from the radius of the neck r_{A-4} before the emission of the α_2-particle, one can get the ratio of the Coulomb barrier penetrabilities $P_2(T_{\alpha_2})/P_1(T_{\alpha_1})$ for the first and second α-particles. Using the experimental values of the kinetic energies T_{α_1} and T_{α_2} and maximum values of energy distributions $W_{\alpha_1}(T_{\alpha_1})$ and $W_{\alpha_2}(T_{\alpha_2})$, the specified estimation of $P_2(T_{\alpha_2})/P_1(T_{\alpha_1})$ is 0.03 for spontaneous quaternary fission of ^{252}Cf. This estimation $P_2(T_{\alpha_2})/P_1(T_{\alpha_1})$ demonstrates that the virtual decay of nucleus $(A-4)$ with α_2 particle flight has subbarrier character in contrast to the virtual decay of nucleus A with α_1 particle flight.

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