The angular and spin distributions of low-energy nuclear fission fragments and collective wriggling - and bending - vibrations of the fissile nucleus in the vicinity of its scission point

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Using the concept [1] about zero wriggling vibrations of a compound fissile nucleus in the vicinity of its point of scission into fission fragments the angular distribution $P(\theta')$ of this fragments for spontaneous and low-energy nuclear fission can be presented in the internal coordinate system (i.c.s.) of axially symmetric fissile nucleus as $P(\theta') = \left|\sum_L \psi_L Y_{L0}(\theta')\right|^2$, where ψ_L is the wave function of wriggling vibrations in *L*–representation, where *L* is relative orbital moment of fission fragments. This function can be presented [2] as $\psi_L = \sqrt{L/C_w}\exp\left(-L^2/4C_w\right)$, where the average value of parameter C_w is equal [1] $\overline{C_w} \approx 132\hbar^2$ for actinide nuclei. Then the average value $\bar{L}$ of orbital momenta L has a sufficiently large value $\bar{L} = 14.4$, that allows to approximate the distribution $P(\theta')$ to the delta-function form, which ensures a good accuracy of the implementation of A. Bohr's hypothesis [3] about the angular distribution $P(\theta')$.

The spin distributions of the fission fragments are traditionally described in terms of the temperature Gibbs distributions $\rho_i(J_i)$: $(2J_i+1)\exp[-\hbar^2 J_i(J_i+1)/\Im_i kT_i]$, $\Im_i$, T_i and J_i are the moment of inertia, temperature, and spin of the *i*-th fission fragment (*i* = 1, 2). For spontaneous and low-energy induced fission the compound fissile nuclei and primary fission fragments in the vicinity of the scission point are in cold nonequilibrium states [3], so it is necessary to take into account [2] only zero transverse bending - and wriggling-vibrations of the specified fissile nuclei when constructing the spin distributions of these fragments. Expressing the normalized distribution function $W(\mathbf{J_1},\mathbf{J_2})$ of the fission fragments over the spins $\mathbf{J_1}$ and $\mathbf{J_2}$ through the product of the squared modules of the wave functions of the zero bending and wriggling vibrations, and integrating over the variables J_2 and ϕ, one can obtain [2] the normalized spin distribution of the first fission fragment: $W(J_1) = 4J_1/(C_b+C_w)\exp\left[-2J_1^2/(C_b+C_w)\right]$ (1). For a fissile nucleus at the values [1] of energies $\hbar\omega_w$ = 2.3 MeV; $\hbar\omega_b$ = 0.9 MeV; and it follows that the vibrational quantum energies $\hbar\omega_w$ and coefficients C_w for the wriggling vibrations are noticeably larger than the analogous values for the bending vibrations. This means that the main contribution to $\bar{J}_1$ is given by wriggling vibrations. Then the calculated value $\bar{J}_1$ = 8.6 correlates well with the experimental [4] average values of the spins of the fission fragments $\bar{J}_1$ = 7-9. However, due to the conservation law of the total spin of the fissile system, the spin distributions of these fragments remain non-equilibrium and are determined with a good degree of accuracy by the formula (1). This conclusion contradicts the concept widely used in the fission theory [3] about the temperature Gibbs character of these distributions.

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