Transition states, K number and mechanism of nuclear fission

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The spectrum of nuclear transition states at the top of the fission barrier determines many essential features of the fission process. In particular, for a nucleus with spin J and parity π with sufficiently high excitation energy, the greater the density of transition states with the same J and π, the higher the probability of fission. If the fissioning nuclei have a spin orientation, then the angular anisotropy of the fragments relative to the orientation axis is determined by the dependence of the fission probability on the projection K of the nuclear spin onto the deformation axis. Thus, the angular distribution of fragments in fission of highly excited nucleus is determined by the dependence of the density of transition states with given J and π on the additional quantum number K. This dependence is described by the Ericson formula [1] for the level density of deformed nuclei. Accounting for this dependence underlies the statistical approach to describing the angular anisotropy of fission fragments (see, for example, [2]). Ericson's result also explained the significant increase in the number of levels in deformed nuclei; this effect, described by the factor of collective enhancement of the level density, is critical for the correct reproduction of the fission probability.

Transition states are taken into account in the currently used methods for calculating fission cross sections (see, e.g., [3]). However, only in a narrow energy band adjacent to the top of the barrier, certain values of K are assigned to the transition states. At higher excitation energies, the density of transition states with given J and π is calculated with the factor of collective enhancement, but without taking into account the quantum number K. This makes it possible to calculate the cross section for nuclear fission, for example, by neutrons. It is this algorithm that is implemented in modern computer programs for nuclear reactions modelling [3]. However, as was shown (see, e.g., [4, 5]), the modification of such programs allows to reproduce the angular anisotropy of fragments with good accuracy at relatively high excitation energies, where the statistical approach is valid. But to do the same at low excitation energies, it is necessary to take into account the quantum number K, as an important characteristic of transition states, in the entire range of excitation energies of the fissioning nucleus.

We propose a method for such consistent consideration of the quantum number K. Its use will make it possible not only to describe numerous data on the angular distributions of fission fragments by neutrons, but also to reconstruct the characteristics of transition states from these data. This will open the way to increasing the reliability of the description of cross sections for nuclear fission by neutrons.

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