Mechanism of Fission of Heavy Nuclei*

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Question is raised concerning the validity of the Vladimirskii mechanism of fission in which the individual nucleons with large component of angular momentum in the direction of the symmetry axis give rise to instability against asymmetric deformation and thus lead to an asymmetric saddle point.

VLADIMIRSKII[1] has proposed a mechanism of fission in which the instability against asymmetric deformation leading to asymmetric saddle point is attributed to the influence of the individual nucleonic states having a large amount of angular-momentum projection in the direction of the symmetry axis of the deformed nucleus. On the basis of the asymmetric saddle point thus achieved, it becomes possible to explain qualitatively a number of fission properties, including the constancy of the fission threshold, the asymmetric mass division, and the asymmetric neutron distribution at symmetric fission. In this note, a question is raised concerning the validity of this mechanism.

In this theory the instability is based on an estimate of the rotational energy $\hbar^2 l_z^2/2Mr^2$ of the nucleon in a deformed nucleus, where $\hbar l_z$ is the projection along the axis of symmetry of the orbital angular-momentum of the nucleon. The order of magnitude of this quantity is taken to be $\hbar^2 l_z^2/2Mr_m^2$ where r_m is the maximum value of the cylindrical coordinate r; when asymmetric deformation is introduced, r_m increases and results in a reduction of the energy.

We note that the use of r_m for an order of magnitude estimate is valid when we compare a number of nuclei deformed according to the same parameters but differing only in the scale of length. It is not justified when we compare a symmetrically deformed nucleus with an asymmetric one. A better estimate may be obtained by assuming the wave function of the nucleon to be constant over the nucleus and taking average of the energy term over the nucleus. When asymmetric deformation is introduced, one side of the nucleus becomes larger while the other becomes smaller. The first order effects of the two sides cancel out. The second order term tends to increase the energy and thus contributes to the stability of a deformed nucleus against asymmetric deformation. Thus, it seems difficult to explain the asymmetric saddle point on the basis of individual nucleonic states with large angular-momentum projection along the axis of symmetry.

It may be noted that when an asymmetrically deformed nucleus is compared with a symmetric one, the first order effect of the change of any property expressible in terms of analytic functions vanishes on account of the fact that the volume of the nucleus is invariant with respect to deformation. It takes a large asymmetric deformation to make the second order effect felt, and the change is gradual. On the other hand, the experimental results of asymmetric mass distribution in fission seem to indicate that as the mass ratio of the fragments increases from unity, the onset of the increased probability for asymmetric fission is rather sudden. Furthermore, this trend is later reversed suddenly. Thus, it is more difficult to explain these sudden changes on the basis of nuclear properties which are expressible in terms of analytic functions than to explain them on the basis of some irregular features, such as the nuclear shell structure as proposed previously.[2–4]

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