NUMBER OF NEUTRONS EMITTED IN SYMMETRIC FISSION OF U^{234} *AND* Pu^{240}

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The number of neutrons ν emitted by U^{234} and Pu^{240} was measured for various fragment mass ratios. It is found that ν sharply rises in the neighborhood of symmetric fission. The dependence of ν on the mass ratio can be satisfactorily correlated with the total kinetic energy of the fragments.

IT has recently been shown [1,2] that the kinetic energy E_k of U^{234}, U^{236}, and Pu^{240} fragments in the case of symmetric fission is about 40 MeV lower than in the case of symmetric fission. Our measurements of the number of emitted neutrons ν as a function of the mass ratio of the fragments for U^{236} showed [3] that there is a distinct correlation between the behavior of the quantities E_k and ν. A minimum number of neutrons is emitted for mass ratios 1.20—1.25, which practically coincides with the position of the kinetic-energy maximum, while as symmetric fission is approached the value of ν increases rapidly. In the present note, we report the results obtained in the case of the fission of U^{233} and Pu^{239} induced by thermal neutrons.

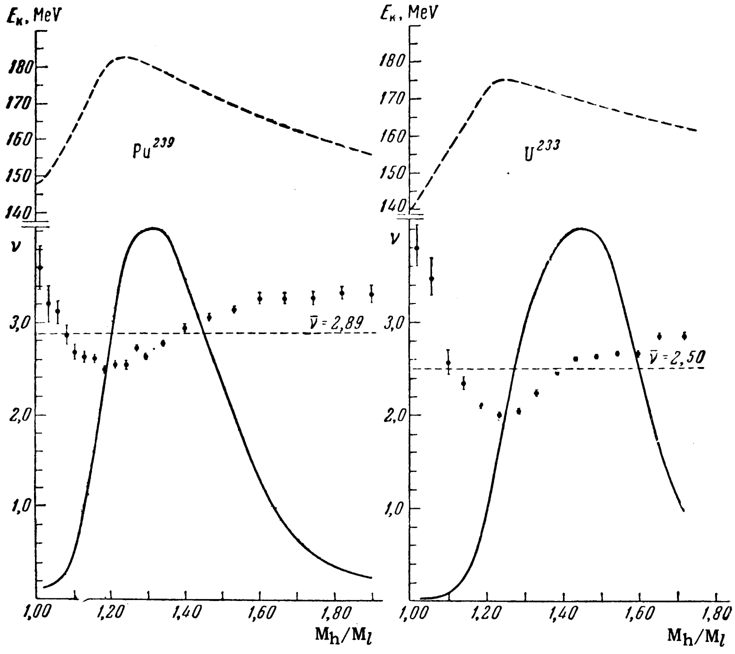
The experiment was carried out with a neutron beam from the thermal column of the reactor. The fragment detector consisted of a double ionization chamber with grids, while the neutrons were recorded in a geometry close to 4π. Layers of uranium and plutonium, 5—6 g/cm^2 thick, were deposited on a colloidal film ($\sim 5\ \mu g/cm^2$) coated with a layer of gold ($\sim 10\ \mu g/cm^2$) by the electrosputtering technique. In the case of Pu^{239}, the amplifiers operated under high pulse rates from α particles. In order to prevent superposition, the pulses were shortened to $\sim 4\ \mu$sec by means of a short-circuited line. The operation of the electronic equipment was triggered by coincidences between the fragments. The coincidence pulse opened the "gate" admitting pulses from the neutron detector to the recording circuit and, at the same time, pulses from the double ionization chamber to the input of the mass-ratio analyzer during a period of 80 μsec. The analyzer recorded all fission fragments whose energy was at least 30 MeV. The fragment counting rate was 20—30 pps, the background in the neutron detector was much less than the desired effect.

The results of the measurements are shown in the figure. The solid curve represents the fragment distribution as a function of the mass ratio with allowance for corrections for the ionization defect (caused by the fact that the total ionization is not strictly proportional to the fragment energy); the points represent the values of the quantity ν with their statistical errors. In the upper part of the figure, the dotted curve represents the kinetic energy of fragment pairs according to the data of [1,2].

It is seen from the figure that the number of neutrons ν has a distinct minimum coinciding in position with the maximum of the fragment kinetic energy. The maximum number of neutrons is emitted in symmetric fission, while the experimental values of the difference $\nu_{max} - \nu_{min}$ are 1.80 ± 0.25 for U^{234} and 1.10 ± 0.2 for Pu^{240}. In the case of U^{236}, we obtained earlier [3] the value 1.6 ± 0.2.

It should be noted that these values are very far from the true values. According to the radiochemical data, [4] the fragment yield ratios of the most probable fission to symmetric fission of U^{234}, U^{236}, and Pu^{240} are 400—500, 600, and 150—180, respectively, while in our experiment, we obtained, as a result of the apparatus effects, the values 200, 210, and 60. The increase in the yields observed in the experiment for ratios close to unity can occur only as a result of the presence in this region of events with values of M_h/M_l characterized by large fragment yields and, consequently, small values of ν. Taking this effect into account, we estimate that the value of the difference $\nu_{max} - \nu_{min}$ should be 4.0 ± 0.7, 4.4 ± 0.6, and 3.2 ± 0.6 neutrons for U^{234}, U^{236}, and Pu^{240}, respectively.

As is known, the sum of the kinetic energy and the excitation energy of the fragments calculated with the aid of a semi-empirical formula [5] is a smoothly varying function of the mass ratio. The results of the present experiment and of [1,2] show qualitatively that the rapid change in the excitation energy and the kinetic energy mutually offset each other. Along with this, it should be mentioned that



Number of neutrons as a function of the mass ratio of the fragments – heavy (M_h) and light (M_l). The solid line represents the experimental distribution of the fragment mass ratio; the dotted line represents the total kinetic energy of the fragments.[1,2]

the physical cause of the observed effects remains unclear.

We suggest that for an explanation of the physical picture it would be of interest to repeat these measurements with equipment having a greater resolving power. It is especially important, in our view, to obtain reliable data on the number of neutrons emitted by the individual fragments.

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