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Abstract

Full Text

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FISSION OF U^{238} NUCLEI BY PHOTONS OF A CONTINUOUS SPECTRUM WITH $E_{\gamma\,\max} =$ 35 MeV AND BY NEUTRONS WITH AN ENERGY OF 14 MeV

In recent years the question of the role of angular momenta in the fission of heavy elongated nuclei has been vigorously discussed ($^{1-5}$). In this connection it seemed of interest to compare the energy and mass distributions of fission fragments of heavy nuclei produced by photons and by neutrons for different angular intervals.

In the investigations a double-pulse ionization chamber with grids was used, operating in the electron-collection regime. The target of fissile material, transparent to the fission fragments, was placed on the common cathode of the chamber. The beam of fission-inducing agents was directed perpendicular to the plane of the target and, consequently, to the plane of the cathode. With such an experimental geometry, the pulses from the chamber electrodes make it possible to obtain information not only on the energy of paired fragments, but also on the angle between the directions of fragment emission and the beam. Indeed, for each fission event the pulses from the collecting electrodes of both halves of the chamber, 1 and 2, give information on the energy of the paired fragments. These pulses are respectively equal to:

$$V_1 = \beta k_1 E_1, \qquad V_2 = \beta k_2 E_2, \tag{1}$$

where E_1 and E_2 are the kinetic energies of the fragments; k_1 and k_2 are the amplification coefficients of the radio-engineering circuits in the circuit of the collecting electrodes of chambers 1 and 2; β is a dimensional coefficient, which, for brevity of exposition, will hereafter be omitted.

The pulse V_3, arising on the common cathode of the chamber, can be represented in the form

$$V_3 = k_3 E - k_3 B E^{5/3} \cos\theta, \tag{2}$$

Fig. 1 and Fig. 2: mass distributions of fragments

Figure 1: Fig. 1 and Fig. 2: mass distributions of fragments

where E is the total kinetic energy of the paired fragments; k_3 is the amplification coefficient of the radio-engineering circuits in the circuit of the common cathode of chambers 1 and 2; B is a coefficient depending on the ratio of the fragment masses, on the medium in which the fragments are stopped, and on the distance between the cathode and the chamber grid; θ is the angle between the direction of fragment emission and the normal to the cathode, i.e., the direction of the beam of fission-inducing agents.

In the measurements, for each fission event, three pulses were simultaneously recorded on a loop oscillograph:

$$V_1 = k_1 E_1, \qquad V_4 = kE, \qquad V_5 = \Delta k E + k_3 B E^{5/3} \cos\theta. \tag{3}$$

The pulse V_4 was obtained by adding V_1 and V_2 with $k_1 = k_2 = k$ by means of the corresponding radio-engineering circuit. The pulse V_5 is the result of subtracting V_3 from V_4. The subtraction was carried out by a radio-engineering circuit with subsequent amplification of the result of the subtraction. Such an operation was neces-

to obtain a stronger dependence on $\cos\theta$. The pulse V_3, in addition to the term depending on $\cos\theta$, contains a term depending only on E. By subtracting, through selection of the corresponding amplification coefficients, the quantity $\Delta k = k - k_5$ in the expression for V_5 can be made arbitrarily small and, consequently, the contribution of the term depending only on E can be reduced to a minimum. The use of the pulse V_5 made it possible to eliminate the introduction of a mechanical collimator for selecting the angle θ, which significantly reduced the measurement time.

Fig. 1. Mass distribution of fragments in fission of U^{238} by neutrons with energy 14 MeV in intervals I—V

Fig. 2. Mass distributions of fragments by mass in photofission of U^{238} for $E_{\gamma\,\max} = 35$ MeV in intervals I—V

Verification of the stability and linearity of the apparatus during the measurements was carried out by feeding signals from a generator of precise amplitudes. In all other respects the block diagram of the setup was analogous to that given in work (^{6}). The sources of the bombarding particles were the neutron generator and the synchrotron of the A. F. Ioffe Physico-Technical Institute of the Academy of Sciences of the USSR. As the target of fissile material, a layer of uranyl acetate deposited on an aluminized collodion film was used. The thickness of the layer was $150\,\mu$g/cm^2. The thickness of the collodion film together with the evaporated aluminum did not exceed $30\,\mu$g/cm^2.

Figure 3

Figure 2: Figure 3

Figure 4

Figure 3: Figure 4

In the course of the measurements, 15,000 fission events of U^{238} by neutrons with energy 14 MeV and 12,000 photofission events were recorded. Simultaneous recording of three pulses V_1, V_4, and V_5 made it possible to construct contour diagrams $E_1 = \varphi(E)$ for 5 equal solid angles. The intervals of θ values for each solid angle were respectively as follows: I (0—34°), II (34—48°), III (48—60°), IV (60—70°), V (70—80). In constructing the contour diagrams, corrections were introduced for the energy losses of the fragments in the target thickness and for the ionization effect.

Using the contour diagrams, one can obtain energy and mass distributions for all the indicated angular intervals. In Fig. 1

it is seen that in the fission of U^{238} nuclei by neutrons with an energy of 14 MeV, as θ increases the total yield of fragments and the contribution of fragments with a large mass ratio $R = m_t/m_l$ decrease, although the positions of the maxima of the curves for all angular intervals practically coincide. The abscissa of the maxima is approximately equal to 1.36. A considerable anisotropy is observed in the distribution of fission fragments. If it is defined as $\Sigma N(0^\circ)/\Sigma N(80^\circ)$, it proves to be 1.40 ± 0.05.

A substantial contribution to this anisotropy is made by fission events with $m_t/m_l > 1.45$. Figure 2 shows the dependence of the fragment yield on θ for photofission. In this case, within the experimental errors there is no dependence of N on θ, and anisotropy is absent. The dependence of the most probable mass ratio of the fragments $\bar{R}$ on θ in fission by neutrons (see Fig. 3), although qualitatively the same for all angular intervals, differs quantitatively, and the curves for different intervals do not coincide.

Fig. 3. Curves of the dependence of the most probable mass ratio of the fragments on the total kinetic energy in the fission of U^{238} by neutrons with an energy of 14 MeV in intervals I-V

The curves for small angles are located higher than the curves for large angles. An analogous dependence for photofission (see Fig. 4) is the same, within the experimental errors, for all angular intervals.

Fig. 4. Curves of the dependence of the most probable mass ratio of the fragments on the total kinetic energy in the photofission of U^{238} for $E_{\gamma\,\mathrm{max}} = 35$ MeV in intervals I-V

It should be noted that the energy imparted to the nuclei in fission by neutrons and photons, corresponding to the maximum of the giant resonance, will be approximately 20 and 15 MeV. If the difference in these energies is inessential, then the differences in the curves $N(R)$ and $R(E)$ with variation of the angle θ for fission by neutrons with an energy of 14 MeV may be due to the momentum received by the nucleus upon capture of a fast neutron.

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