

**Academician of the
Academy of Sciences of
the Ukrainian SSR A. P.
KOMAR, B. A.
BOCHAGOV, V. I.
FADEEV**

1963

SovietRxiv

View the original and related papers at <https://sovietrxiv.org/items/ru-196301.58111>

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.

Fig. 1. Contour diagram for the case of fission of Th^{232} nuclei by neutrons with an energy of 14 MeV

Figure 1: Fig. 1. Contour diagram for the case of fission of Th^{232} nuclei by neutrons with an energy of 14 MeV

Abstract

Full Text

Academician of the Academy of Sciences of the Ukrainian SSR A. P. KOMAR, B. A. BOCHAGOV, V. I. FADEEV

FISSION OF Th^{232} NUCLEI BY NEUTRONS WITH AN ENERGY OF 14 MeV AND BY PHOTONS OF A CONTINUOUS SPECTRUM WITH $E_{\gamma \text{max}} = 90 \text{ MeV}$

Experiments in recent years on the fission of gold, lead, bismuth, and radium by various particles (¹⁻³) have shown that, at intermediate excitation energies of nuclei lighter than thorium, symmetric fission by mass is clearly manifested, with characteristics different from those of asymmetric fission, which is observed for heavier nuclei. It is known that, for heavy nuclei, along with fission products very different in mass, fragments with equal or nearly equal masses are also observed.

In this connection, the question is being discussed in the literature of the existence of symmetric fission as an independent process in the fission of elements of the thorium group and heavier nuclei (⁴⁻⁶). One of the proofs of the presence of a symmetric type of fission in heavy nuclei may be the observation on the contour diagram of a peak in the "symmetric" region.

In the present work, fission of Th^{232} induced by neutrons with an energy of 14 MeV and by photons of a continuous spectrum with a maximum energy of γ -quanta $E_{\gamma \text{max}} = 90 \text{ MeV}$ was investigated. The aim was to study, for various angles between the fission directions and the neutron (photon) beam, the energy distributions of fragments with fixed ratios of their masses. To solve this problem, a double-pulse ionization chamber was used. To select fission directions at a given angle to the neutron (photon) beam, electrical collimation was employed (⁷). As the target, a layer of thorium nitrate deposited on an aluminized collodion film was used. The thickness of the collodion film with evaporated aluminum did not exceed $30 \mu\text{g}/\text{cm}^2$. The thickness of the thorium nitrate layer was $150 \mu\text{g}/\text{cm}^2$ for fission by photons and $50 \mu\text{g}/\text{cm}^2$ in the case of fission by neutrons.

Fig. 2. Contour diagram for the case of fission of Th^{232} nuclei by photons with $E_{\gamma\text{max}} = 90$ MeV

Figure 2: Fig. 2. Contour diagram for the case of fission of Th^{232} nuclei by photons with $E_{\gamma\text{max}} = 90$ MeV

Fig. 1. Contour diagram for the case of fission of Th^{232} nuclei by neutrons with an energy of 14 MeV

In the fission of Th^{232} by neutrons with an energy of 14 MeV, about 21,000 fission events were recorded. From the measurement results a contour-

diagram shown in Fig. 1. The contour diagram was constructed in the coordinates $E, m_t/m_1$, where E is the total kinetic energy of paired fragments, and m_t/m_1 is the fragment mass ratio. Corrections for losses in the target thickness and for the ionization defect were introduced into the results presented in Fig. 1 (as well as in all subsequent figures).

It is evident from Fig. 1 that, alongside the "hill" corresponding to asymmetric fission with the most probable value of the mass ratio $m_t/m_1 = 1.53$, a hill is clearly revealed in the region of mass ratios corresponding to mass-symmetric fission.

Fig. 2 shows a contour diagram constructed for fission of Th^{232} by photons of a continuous spectrum with $E_{\gamma\text{max}} = 90$ MeV (the number of registered photofission events was 18,000). As in the case of fission by neutrons, a peak corresponding to mass-symmetric fission is clearly distinguished. This had previously been observed upon irradiation of Th^{232} by photons with $E_{\gamma\text{max}} = 70$ MeV⁽⁸⁾.

Fig. 2. Contour diagram for the case of fission of Th^{232} nuclei by photons with $E_{\gamma\text{max}} = 90$ MeV

As already noted above, the method used in the work made it possible to study the energy and mass distributions of fission fragments for different angles relative to the beam of fission-inducing agents (angle θ). From the measurement results, series of graphs were constructed characterizing the distribution of E at fixed values of m_t/m_1 for the following five intervals of the angle θ : I (0—34°); II (34—48°); III (48—60°); IV (60—70°); V (70—80°). Figure 3 presents graphs of E at various fixed values of m_t/m_1 for the I and V angular intervals in the case of fission of Th^{232} by neutrons with energy 14 MeV. The most interesting feature of the graphs is the presence of two peaks in the distribution of the total kinetic energy E for the range of fragment mass ratios $m_t/m_1 = 1.1 \div 1.2; 1.2 \div 1.3$ in fission of Th^{232} in the direction of the neutron beam (I angular interval, Fig. 3a). As m_t/m_1 increases from 1.1 to 1.3, the positions of both peaks shift toward lower energies. The distance between them, within the limits of measurement error, remains constant and is 18 MeV. From the graphs in Fig. 3

Figure 3: Distributions of the total kinetic energy of Th-232 fragments for fixed mass ratios in fission by 14 MeV neutrons.

Figure 3: Figure 3: Distributions of the total kinetic energy of Th-232 fragments for fixed mass ratios in fission by 14 MeV neutrons.

it is also evident that the most probable value of the kinetic energy of symmetric fission ($m_t/m_1 = 1 \div 1.1$) is 10 MeV less than the most probable value of E at $m_t/m_1 = 1.3 \div 1.4$. Two peaks in the distribution of the total kinetic energy of fragments at $m_t/m_1 = 1.1 \div 1.3$ are also observed for intervals II-IV, the separation becoming less distinct with increasing angle θ , and for interval V (Fig. 3b) only one peak is found.

If it is assumed that the left peak in the distribution of E for $m_t/m_1 = 1.1 \div 1.3$ belongs to the symmetric type of fission, then the following conclusions can be drawn: 1) the symmetric type of fission, like the asymmetric type, has a dispersion in the fragment mass distribution extending at least to $m_t/m_1 \leq 1.4$; 2) the symmetric type of fission corresponds to a smaller value of E .

The changes occurring in the distribution of kinetic energy upon

an increase in the angle, discussed above, may be due to the dependence of the mass and energy distributions of fragments of the symmetric and asymmetric types of fission on the direction of fission in cases where a considerable anisotropy is observed in the angular distribution of the fragments (⁷).

Fig. 3. Distributions of the total kinetic energy of Th²³² fragments for fixed mass ratios in fission by 14 MeV neutrons. *a*–I angular interval, *b*–V angular interval

The angular distribution of fragments from fission of Th²³² by neutrons with an energy of 14 MeV, obtained in the present work, is shown in Fig. 4. The circles denote the experimental points. The solid curve is described by the equation $\sigma(\theta) = 1 + A \cos^2 \theta$, where $A = 1$. The curve is normalized to the experimen-

tal data at $\cos \theta = 0.93$. Thus, the angular anisotropy $\sigma(0^\circ)/\sigma(90^\circ) = 2$. The indicated anisotropy pertains to the overall angular distribution, independently of the type of fission. However, it may turn out that the angular distributions of the symmetric and asymmetric types of fission are different, in particular that their anisotropies are different. Then this may lead to the transition observed in this work from two peaks in the distribution of E at $m_t/m_1 = 1.1 \div 1.3$ to one peak as the angle θ increases.

In conclusion, let us point out one methodological reason that may affect the poorer resolution of the two peaks in the distribution of E as the angle θ increases. The point is that the effective target thickness, for the method used in the present work to select the direction, increases as $t = t_0/\cos \theta$, where t_0 is the target thickness in the direction of the neutron beam ($\theta = 0^\circ$). Consequently, for $t_0 = 50 \mu\text{g}/\text{cm}^2$ the target thickness for fragments emitted into the

Fig. 4. Angular distribution of fission fragments of Th^{232} by neutrons with energy 14 MeV

Figure 4: Fig. 4. Angular distribution of fission fragments of Th^{232} by neutrons with energy 14 MeV

V interval will be $t \simeq 250 \mu\text{g}/\text{cm}^2$. In order to determine how much an increase in the source thickness to $250 \mu\text{g}/\text{cm}^2$ affects the energy resolution, for angular intervals I-V a series of graphs was constructed, analogous to those shown in Fig. 3, for the case of fission of Th^{232} by photons with $E_{\gamma\text{max}} = 90 \text{ MeV}$. At the indicated photon energy the angular distribution of fragments, as is known, is isotropic and one can therefore observe the direct influence of the change in source thickness on the energy and mass distributions of fission fragments as the angle θ increases. Analysis of the curves of the distributions of the total kinetic energy of the fragments E , at specified mass ratios m_t/m_1 , constructed for the case of photofission of Th^{232} , showed that even at target thicknesses greater than $250 \mu\text{g}/\text{cm}^2$ two peaks can be distinguished in the range of fragment mass ratios $1.1 \div 1.3$. The presence of two maxima in the distribution of E for mass ratios $1.1 \div 1.4$ was observed earlier in work ⁽⁹⁾, where photofission of U^{232} nuclei was studied at $E_{\gamma\text{max}} = 70 \text{ MeV}$ and a source thickness of $320 \mu\text{g}/\text{cm}^2$.

Fig. 4. Angular distribution of fission fragments of Th^{232} by neutrons with energy 14 MeV

Thus, the observed transition in the E distributions from two peaks (for $m_t/m_1 = 1.1 \div 1.2$; $1.2 \div 1.3$) in fission along the neutron beam to one peak as the angle θ increases is not connected with the influence of the source thickness and is apparently due to different anisotropy of the angular distributions of the symmetric and asymmetric types of fission.

Physico-Technical Institute named after A. F. Ioffe
Academy of Sciences of the USSR

Received
13 V 1963

CITED LITERATURE

1. A. W. Fairhall, R. C. Jensen, F. F. Neusil, Proc. Second U. N. Intern. Conf. on the Peaceful Uses of Atomic Energy, **15**, Geneva, 1958, p. 452.
2. A. W. Fairhall, Phys. Rev., **102**, 1335 (1956).
3. R. C. Jensen, A. W. Fairhall, Phys. Rev., **118**, 771 (1960).
4. G. P. Ford, Phys. Rev., **118**, 1261 (1960).

5. H. W. Newson, Phys. Rev., **122**, 1224 (1961).
6. Yu. A. Selitskii, V. P. Eismont, JETP, **34**, 1005 (1962).
7. A. P. Komar, B. A. Bochagov, V. I. Fadeev, DAN, **146**, No. 5, 1051 (1962).
8. B. A. Bochagov, A. P. Komar, G. E. Solyakin, V. I. Fadeev, Atomic Energy, **11**, 540 (1961).
9. B. A. Bochagov, A. P. Komar, G. E. Solyakin, JETP, **38**, 1374 (1960).

Note: Figure translations are in progress. See original paper for figures.

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.