INFLUENCE OF NUCLEAR SHELLS ON THE DISTRIBUTION OF THE KINETIC ENERGY OF FRAGMENTS IN FISSION BY FAST NEUTRONS

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Submitted to JETP editor February 21, 1959

J. Exptl. Theoret. Phys. (U.S.S.R.) **36**, 1932-1933 (June, 1959)

A double ionization chamber was used to obtain data on the distribution of the total kinetic energy of the fragments in fission of U^{238} by 14.9-Mev neutrons. The measured values of the energy were corrected for the ionization defect. From the experimental half-widths of the distribution of the kinetic energy we subtracted the broadening due to the distribution of the charge, to the effect of recoil from the neutrons, to fluctuations of the number of evaporated neutrons, to the instrumental error, and to the averaging over the final interval of the mass ratio. The dependences thus obtained for the mean kinetic energy E and for the half-width ΔE of its distribution on the fragment mass ratio are shown in Fig. 1. For comparison, the same figure shows the distribution of the kinetic energy of the fragments in fission of U^{235} by 14.1-Mev neutrons[1] and the distribution of the dispersion calculated for this case.

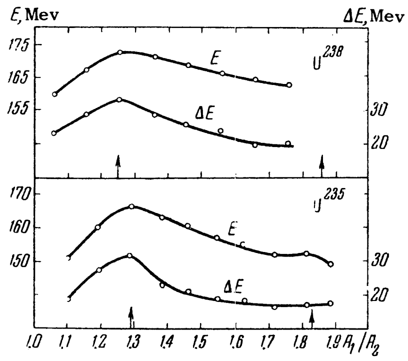

FIG. 1. Dependence of the total kinetic energy and its distribution half-width on the ratio of the fragment masses. The positions of the "magic" fragments are noted on the graph by vertical arrows.

It is seen that both E and ΔE have maximum values at a fragment mass ratio of 1.25 — 1.3. The presence of a maximum on the curve for the dependence of the total kinetic energy on the mass ratio was noted earlier by Brunton and Hanna[2] in an investigation of the fission of U^{233} and U^{235} by thermal neutrons. Similar maxima in the kinetic-energy distribution are observed at different mass

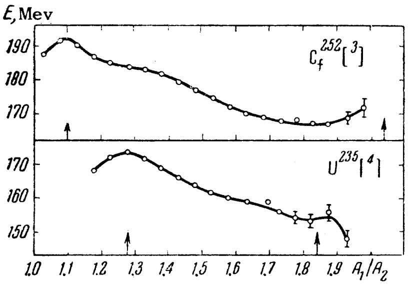

FIG. 2. Change in the total kinetic energy as a function of the ratio of the fragment masses. The curves were plotted from the experimental data of Fraser and Milton[3] and Stein.[4] The positions of the "magic" fragments are indicated by arrows.

ratios for all known cases of fission of heavy nuclei. Figure 2 shows the distributions of the kinetic energies in fission of U^{235} by thermal neutrons and in the spontaneous fission of Cf^{252}, obtained by measuring the time of flight. It is interesting to note that in all cases the kinetic energy has a maximum when the heavy fragment has a mass number close to 132, and probably, represents a nucleus with filled shells of 50 protons and 82 neutrons. In addition, there is a certain kink at a fragment mass ratio corresponding to a light fragment with mass number 82 — 84, probably with a closed shell of 50 neutrons. A similar influence of closed shells is observed also in the variation of the energy dispersion (ΔE) with the fragment mass ratio, which we determined for U^{233} and U^{235} by processing the results of Brunton and Hanna.

It can be assumed that the foregoing features are connected with the influence of the degree of filling of the nuclear shells on the shape of the fragment during the instant of separation. Starting with this assumption, qualitative conclusions can be drawn concerning the character of the dependence of the neutron emission on the fragment mass. Indeed, one might think that a "magic" undeformed fragment should emit fewer neutrons than its mate, the "non-magic"* one, i.e., most neutrons should be emitted from the lighter fragment at small mass ratios and from the heavier one at large mass ratios. Such conclusions are in agreement with the data of Fraser and Milton for the fission of U^{233} by thermal neutrons[5] and the data of Whetstone[6] on spontaneous fission of Cf^{252}.

*It is assumed here that the degree of deformation of the fragments during the instant of separation determines, essentially, the excitation after separation.

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Translated by J. G. Adashko
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INTERACTION OF ACCELERATED NITROGEN NUCLEI WITH BISMUTH

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Submitted to JETP editor February 23, 1959

J. Exptl. Theoret. Phys. (U.S.S.R.) **36**, 1933-1935 (June, 1959)

We have investigated reactions that lead to the production of α-active isotopes upon interaction of accelerated N^{14} nuclei with bismuth. A stack of ten layers of bismuth (~ 0.8 mg/cm^2 each), deposited on thin nickel foils ($\sim 1.5\,\mu$) was exposed in the internal beam of the cyclotron to nitrogen ions with energies of ~ 102 Mev. The foils were attached to a special sampler in front of the current collector, to control the ion current to the target during the irradiation process. The nitrogen ions lost approximately 3 Mev upon passing from one layer of bismuth to another. The results of Oganesyan[1] were used to calculate the deceleration of the ions. To avoid overheating the target, the current did not exceed $0.01\,\mu$a.

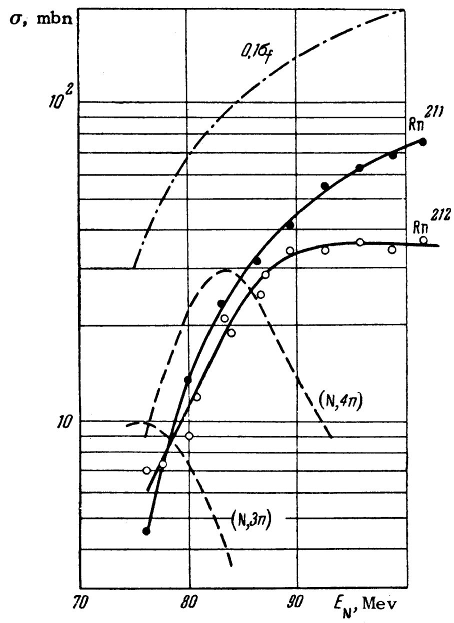
Using a luminescent α-particle counter insensitive to the β and γ background, we investigated in detail the decay of the activity induced in the bismuth layers. The α-particle energy was measured with an ionization chamber (emitters 1 and 2) and a photoemulsion (emitter 3). We were thus able to establish the production of the α emitters, the characteristics of which are indicated in the table (emitters 4 and 5 were not investigated in detail).

The first α activity must be quite unambiguously ascribed to Rn^{211} (T = 16 hours, E_α = 5.82 Mev) and to the At^{211} (T = 7.5 hours, E_α = 5.89 Mev) and Po^{211} (T = 0.5 sec, E_α = 7.43 Mev)

α-emitter	1	2	3	4	5
T	15±2 hr	25±2 min	150 days	2—3 min	5—7 hr
E_α, Mev	5.7±0.2 7.3±0.2	6.1±0.2	5.2±0.3		

which are in equilibrium with it. Emitter 2 is obviously also a radon isotope — Rn^{212} (T = 23 min, E_α = 6.23 Mev). It must noted that Rn^{209}, Rn^{208}, and Fr^{212} do not differ greatly from Rn^{212} in the half-lives and energies of the α particles. However, estimates show that the contribution of these isotopes into the observed activities is small. The Rn^{209} may be the result of α-decay of Ra^{213} (T = 2.7 min), which is the product of the reactions (N, 6n) and (N, α6n). From the yield of the α emitter with half-life of 2 — 3 minutes we can surmise that, for nitrogen ions with energy 100-Mev (which, obviously, corresponds to the maximum probability of the reaction with emission of six neutrons), Rn^{209} can cause not more than 5 or 10% of the observed activity with a half-life of 25 minutes. The contribution of Rn^{208} and Fr^{212} should be even less, since reactions with emission of not less than seven nucleons would be necessary for their appearance.

The dependence of the cross sections for the production of Rn^{212} and Rn^{211} on the energy of the nitrogen ions is shown in the diagram. The



relative course of the curves is determined, essentially, by statistical errors, which do not exceed 10%. The inaccuracy in determining the absolute value of the cross sections is on the order of 50%. It is connected with the errors that arise