Determination of isobar composition and yields in mass distribution of heavy fission products in $^{239}Pu(n_{th},f)$ reaction

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The experimental researches of mass, charges and energetic distributions of fission products (FP) have revealed a number of features and laws in these distributions. The most of experimental data is received by radiochemical methods, which give the information about late stage of fission process and do not allow to measure kinetic energy and velocity of FP Instrumental technique (ionisation chamber, the semiconductor detectors, time of flight) allow to measure velocity of FP, but have insufficient mass resolution (1,5 - 3 a.m.u.). Comparison of experimental data received by identical methods; show difference in them. It is connected with insufficient accuracy of measurements and insufficient resolution of experimental techniques. The most precise and reliable results are received with use the deflection method of the FP in the homogeneous consecutively located electrical and magnetic fields. In resent time on the horizontal channels of research reactors some plants work with using deflection method of charged particles in magnetic and electrical fields. There is "LOHENGRIN" mass spectrometer in Grenoble (France) [1] and INP AS mass spectrometer in Tashkent [2]. Besides on the Grenoble reactor works "Cosi-Fan-Tutte" time of flight spectrometer [3], combining time of flight method, ionization chamber and semi-conductor detectors. The experimental results obtained from "LOHENGRIN" mass spectrometer and "Cosi-Fan-Tutte" time of flight spectrometer and also from INP AS mass spectrometer have good coincidence. These spectrometers defines necessary energy and mass ranges of FP, identifies with high accuracy FP mass numbers and determines them kinetic energies. Use of such experimental results permit to evaluate existing fission models and describe all stages of nuclei fission process by neutrons in more detail.

Super asymmetrical modes investigations of actinide nuclei fission is one of the important and actual problem of nuclei fission physics recently, which is given a lot of attention, both from the experimenters and the theorists. On "LOHENGRIN" mass spectrometer super asymmetrical modes of light group FF were in detail investigated [4,5]. However, the knowledge of this process cannot be complete without study of the FP physical characteristics in heavy group. The measurements of mass and energy distributions of FP in heavy group and available experimental results in FP light group, received on "LOHENGRIN" mass spectrometer will to have more complete and objective physical picture of fission process.

For search of isobar nuclei in mass distributions of heavy FP of ^{239}Pu nuclei by thermal neutrons we used experimental data from [6]. In [6] experimental data for FP mass yields depending from effective charge z* in mass range from A=125 to 157 a.m.u. are resulted. At figure 1 such experimental dependence of FP yields Y_i (A_i) =f(z*) and processing of this dependence by Gauss distribution with an error to one σ for each z* is presented.

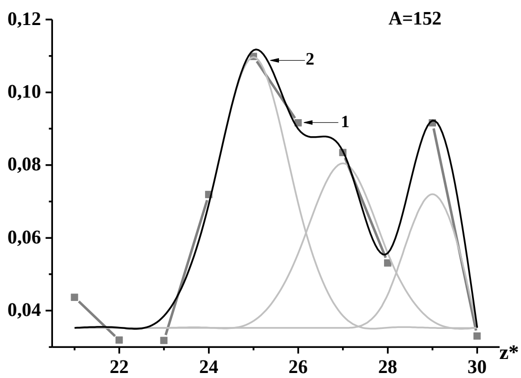

Fig.1 The curve 1 - experimental data, curve 2– treatment by Gauss distribution

The basic difficulty consisted in correct transition from measured z* to charges of heavy fragments at the moment of nuclear fission. For this purpose we used the modified expression from [6]in the form of:

$$z_i^* / z_i = \left[1 + \left(V_i / z_i^{\alpha} \cdot V_0\right)^{-1/k}\right]^{-k} .$$

Here z_i* and z_i - the measured effective charge of the i-th ion with mass number A_i and a fragment charge corresponding to it, V_i - velocity of ion, V_o - average velocity of electrons interacting with fragment in the target matter and influencing to formation of an effective charge of the ion. Velocity V_i was defined with use of measured value E_k for each product. Velocity V_o can changes in limits from $V_o = 2.2\times10^8$ cm/s - electron velocity in the first orbit of hydrogen atom to 3.6×10^8 cm/s [7], constants: α =0.45 and k =0.6 are taken as from [7]. In Table 1 the results of isobar nuclei estimation for A= 152 are presented.

With use of this approach the search of isobar nuclei of ^{239}Pu nuclei FP by thermal neutrons in mass numbers range from A=125 to A=157 is executed. Further, for certain values of isobar nuclei yields comparison with theoretical data [8] is executed. The comparison of obtained isobar yields for A=152 with evaluated data from [8] are shown in the table 2. Measurements of heavy fragments of ^{239}Pu nuclei fission by thermal neutrons in ranges of mass from A_i=125 to 157, kinetic energies from E_k = 45 to E_k=87 MeV and effective ionic charges from z * = 18 to z * = 30 are executed on mass spectrometer of research nuclear reactor of WWR-SM INP Uz AS. 102 isobar nuclei from the measured fission fragments and their partial yields of are defined.

Table 1: Determination of isobar composition for A= 152

z*	E_k, MeV	$V_i\times10^8$, cm/s	$V_o\times10^8$, cm/s	z_i	Izobar nuclei
25±0.94	73.73	9.67	3.14	60.06	$^{152}Nd_{60}$
27±0.93	77.23	9.90	2.94	60.96	$^{152}Pm_{61}$
29±0.20	80.23	10.09	2.63	58.98	$^{152}Pr_{59}$

Table 2: The comparison of obtained experimental yields with evaluated data []

Evaluated data from [3]			Our experimental data	
Izobar nuclei	Ind. Yield	Cum. Yield	Izobar nuclei	$Y_i(A_i)$
^{152}Ce 3.1 s	0.0118	0.0118		
^{152}Pr 3.2 s	0.16	0.172	$^{152}Pr_{59}$	0.126
^{152}Nd 11.4 m	0.37	0.542	$^{152}Nd_{60}$	0.287
$^{152}Pm^m$ 7.5 m ^{152}Pm 4.1 m	0.0167 0.0167	0.0167 0.559	$^{152}Pm_{61}$	0.229
^{152}Sm stable	4.30E-04	0.576		

$Y_i(A_i)$ - yield of isobar nucleus.

References

[1] E. Moll, H. Schrader et. al. Kerntechnik, v.19, 1977, p.374.

[2] U.A. Arifov, A.D. Belyaev et. al. Dokl. AS USSR, v.204, 1972, p.586.

[3] U.A. Arifov, A.D. Belyaev, V.I. Kogan et.al. DAN SSSR, 204,1972, p.586.

[4] N. Boucheneb, P. Geltenbort et. al. Nucl. Phys., v. A 502,1989, p.261.

[5] I.Tsekhanovich, H.-O.Denschlag et al. Nucl.Phys. A.688, 2001, p.633.

[6] G.A. Abdullaeva, Yu.N. Koblik, V.P. Pikul, A.P. Morozov, A.F. Nebesny, Charge, Mass and Energy Distributions of Fission Fragments in ^{235}U and ^{239}Pu (n_{th}, f) Reactions, International Journal of Nuclear Energy Science and Engineering, Volume 3, Issue 3, 2013, pp 72-77.

[7] V.S. Nikolaev and I.S. Dmitriev, On the equilibrium charge distribution in heavy element ion beams, Volume 28A, №4, 1968, 277.

[8] T.R. England and B.F. Rider, Fission Product Yields per 100 Fissions for ^{239}Pu Thermal Neutron Induced Fission Decay, LA-UR-94-3106, ENDF-34.