FORMATION MECHANISM OF FISSION FRAGMENTS AND THE LIGHT NUCLEI IN VARIOUS NUCLEAR REACTIONS

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One of the main problems of a fission process in how to determine the initial conditions when the nucleus breaks into two fragments [1].

Correlation for initial configuration of fission fragments Z_L and Z_H is used:

$$\frac{Z_L Z_H e^2}{r_F} = E_L + E_H = E_L(1 + \frac{M_L}{M_H}) \tag{1}$$

The most probable experimental data for E_L and E_H give $r_F \simeq 20$ Fm$> R_0 \sim M_0^{1/3}$ ($M_0 = M_L + M_H$).

Does the model correspond to reality?

Let us use a similar approach for light nuclei experimental energetic spectra formed in various nucleus reactions and light nuclei formed from ternary fission.

A Coulomb interaction in the nucleus reactions is shown in Fig.1 and it has the form: $\frac{E_{m1}}{Z_{m1}} - a_{m1} = \frac{Z_1}{r_m}$ (E_{m1} energy of a light nucleus with charge Z_{m1}; a_{m1}, r_m are constants)

E_L and E_H have a similar dependence on charges Z_L and Z_H for the fission fragments.

A graph in Fig.2 is compiled from the light nuclei energetic spectra data [2].

Fig.2 shows linear dependece of quantities $\frac{1}{v_{eem1}} = \sqrt{\frac{m_1 Z_1 Z_{m1}}{2E_{m1}}}$ on a light nuclei mass m_1.

One can see that a light nuclei has a recoil, when it takes off, corresponding to some effective mass $m_2 \ll M_1 = M_0 - m_1$.

It is equal to m_1 is subjected to the Coulomb repulsion and attraction at the expense of energy of a hypothetic mass m_2 recoil.

The quantity m_2 does not depend on M_0 and Z_0 of the initial nucleus.

The dependence (1) has the form for this case:

$$\frac{Z_1 Z_{m1} e^2}{r_{m1}} = E_{m1}(1 + \frac{m_1}{m_2}).\text{We have here:} r_{m1} < R_0 \sim M_0^{1/3}.$$

It follows from the m_2 properties analysis that m_2 has a charge $Z_{m2} = -Z_{m1}$ and a negative Coulomb potential.

It is supposed that m_2 is a hole and it forms a nucleus dipole together with a light nucleus m_1. Such a dipole may get a γ energy quantum from a nucleus:

$$E = h\omega = \frac{Z_1 Z_{m1} e^2}{r_1} \tag{2}$$

The energy divides with m_1 and m_2 according to the momentum conservation law. The correlation between the γ quantum wave length and the absorb dipole dimension may be obtained from (2):

$$\alpha\ \lambda = \frac{r_1}{Z_1 Z_{m1}}.$$

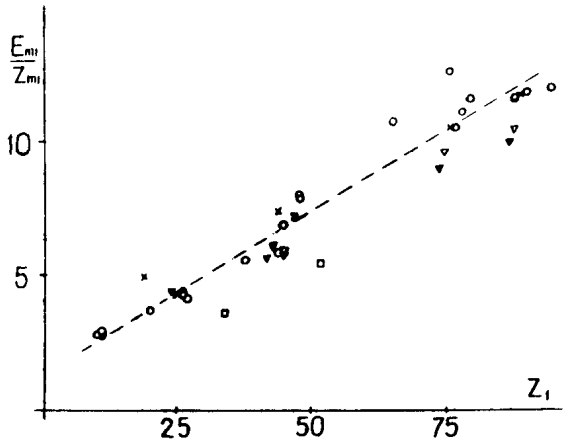

Fig.1. Dependence of the most probable quantities of kinetic energies of light nuclei formed in various nucleus reactions $\frac{E_{m1}}{Z_{m1}}$ (energies are reduced to single charge of light nuclei), on residual nucleus charge $Z_1 = Z_0 - Z_{m1}$.
The data is presented for ^4He (o), ^7Li (×), ^{10}Be (∇), ^{11}B (▼) formed when 1 GeV protons iteract with nuclei Ti, Ni, Ag, Sn, Au, U. The data is shown for ^4He (o), formed when ^{40}Ar (333 MeV) interacts with ^{110}Sn, ^{154}Sm, ^{197}Au. Data is also shown for ^4He from the reaction of proton 23 MeV energy interacts with nuclei Mg, Al, Cu, Pd, Pt. The results are shown for ^{16}C (□) formed when the protons with energy 350 GeV interacts with nuclei Xe and Kr. The values $\frac{E_{m1}}{Z_{m1}}$ are presented in MeV

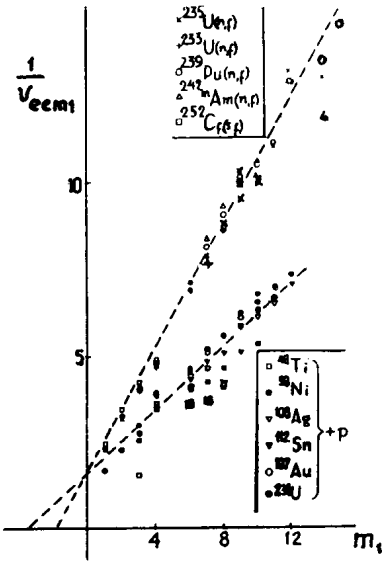

Fig.2. Dependence of the most probable quantities $\frac{1}{v_{eem1}}$ on m_1 for light nuclei of ternary fission ^{233}U, ^{235}U, ^{239}Pu, ^{242m}Am by thermal neutrons and of spontaneous fission ^{252}Cf and the same dependence for nucleus reactions when 1 GeV energy protons interact with nuclei of Ti, Ni, Ag, Sn, Au, U. The data for $\frac{1}{v_{eem1}}$ are obtained by reducing light nuclei energies m_1 corresponding to them, to a single charge of residual nucleous $Z_1 = Z_0 - Z_{m1}$ and a single charge of the light nucleous Z_{m1}. It has been obtained from the data averaging: for the ternary fission $m_2 = 1.88$; $\frac{1}{v_0} = 1.65(\frac{\text{a.m.u.}}{\text{MeV}})^{1/2}$ and for the nucleous reactions $m_2 = 3.59$; $\frac{1}{v_0} = 1.64(\frac{\text{a.m.u.}}{\text{MeV}})^{1/2}$

The m_2 hole is situated in a residual nucleous. But the interaction of m_2 with a residual nucleous remains uncertain because of absence of residual nucleous energy measurings.

The graphs similar to those in Fig.2 may be compiled for the fission fragments.

Fig.3 shows that for a light fragment the dependence $\frac{1}{v_{eeL}}$ on M_L is similar to the dependence $\frac{1}{v_{eem1}}$ on m_1 for light nuclei.

M_{L0} is a hole in a heavy fragment M_H.

The equality of the momentum quantity can be made from Fig.3 and the experimental data: $\mid p_L \mid = \mid p_{L0} \mid = \mid p_{H0} \mid = \mid p_H \mid$.

The momentum $\vec{p}_L$ is directed from the fragment M_H centre, and $\vec{p}_{Lo}$ is directed to the centre.

When a dipole decays a hole moves to the centre of M_H.

M_{H0} is a part of M_H mass. It moves against M_{L0} when the dipole decays and it fills up a hole.

Thus, the data for fission corroborate the results, obtained for the light nuclei.

The fission process mechanism we assume excludes the necessity of introducing the initial Coulomb configuration with $r_F \simeq 20$ Fm as it follows from (1).

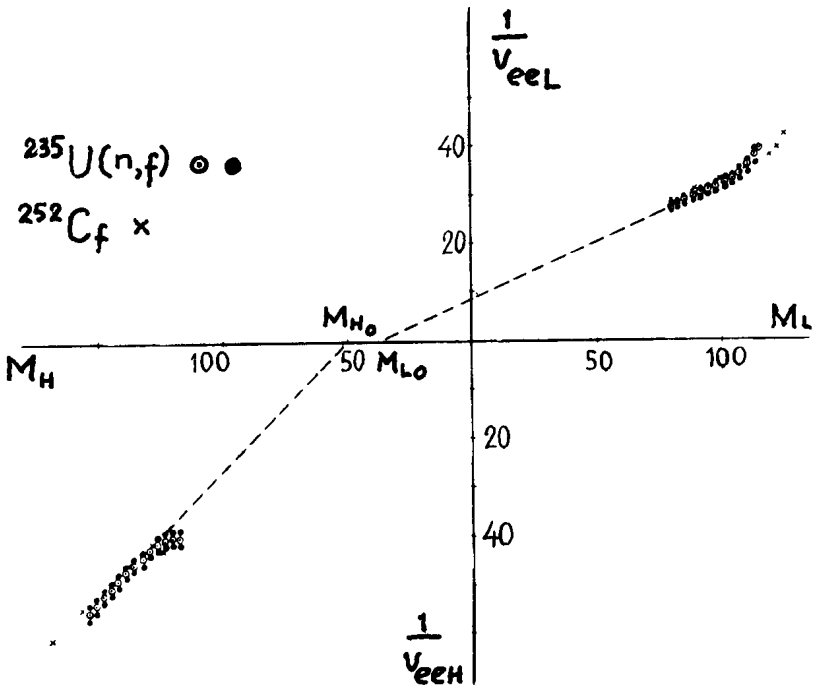

Fig.3. Dependence of values $\frac{1}{v_{eeL}} = \sqrt{\frac{M_L Z_L Z_H}{2E_L}}$, $\frac{1}{v_{eeH}} = \sqrt{\frac{M_H Z_L Z_H}{2E_H}}$ on masses of light (M_L) and the heavy fragments (M_H). Data for induced fission $^{235}U(n,f)$ and spontaneous fission ^{252}Cf are presented. Points corresponding to ^{252}Cf are indicated as ($\times$) (the most probable values are taken). Most probable quantities for $^{235}U(n,f)$ are indicated ($\odot$) and their values on FWHM of energetical distribution are indicated as ($\bullet$). Values $\frac{1}{v_{eeL}}$, $\frac{1}{v_{eeH}}$ are given in units $(\text{a.m.u./MeV})^{1/2}$

REFERENCES

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2. *Nikitin A.M.* Preprint PNPI–1952. Gatchina, 1994. 30 p.