THE SEARCH FOR SUPER-HEAVY TRANSURANIC ELEMENTS IN METEORITIC PHOSPHATES BY USING OF THREE-PRONG FISSION EVENTS

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Introduction

Search and identification of superheavy elements (SHE) of Z≥110 in a nature were carried out till now by registration in olivine from pallasites of super-long tracks - traces of braking of high-energy SHE nuclei formed a part of the galactic cosmic rays (GCR) [1-3]. For removal of a background from high track density due to iron nuclei (VH – group) before chemical etching the olivine crystals were annealing at the certain conditions. Thus, however, occurred (6-8) multiple shortening of the longest tracks concerning nuclei of Z ≥ 54. Calibration of track lengths formed in olivine by the accelerated nuclei ^{238}U with energy ~ 30 and ~ 70 MeV/nucleon [4], has shown, that the maximum in a length spectrum of annealed and then etched tracks for them is L = 230 ± 25 μm. Hence, founded at that time 11 tracks with L ≥ 340 μm were referred to nuclei of trans-uranic elements.

The new approach to the decision of SHE problem is based on an opportunity of registration of ternary spontaneous fission cases [5]. The experimental researches of three-prong fission fragment tracks of super-heavy nuclei were performed firstly by Perelygin V.P. et al. more than 20 years ago [6]. At these experiments were observed the unique events of ternary spontaneous fissions of the compound nuclei with Z = 110, formed at capture by uranium nuclei of accelerated up to ~ 10 MeV/nucleon of argon ions:

$$^{238}U_{92} + {}^{40}Ar_{18} \rightarrow {}^{278}C_{110} \rightarrow A_1 + A_2 + A_3.$$

It was determined, that the probability of ternary spontaneous fission of SHE in relation to fission on two fission fragments is ≤ 3x10^{-4}. But for all that is the essential distinctions of probability of ternary fission for the SHE and ^{238}U nuclei: for the first it appears on three - four order of magnitude higher [6,7].

In the present report a number of methodological questions concerning probability of detection and identification of three-prong fission fragment track cases in the phosphate crystals from meteorite - pallasites are considered.

The basic track sources in meteorite matter

Prevailing part of tracks, observed in crystals of silicate minerals of meteoritic matter are formed by: (1) fragments of spontaneous fission of ^{238}U and extinct ^{244}Pu; (2) nuclei of VH-group (23 ≤ Z ≤ 28) in GCR; and (3) induced fission of heavy, mainly Th and U, elements under action of primary and secondary nuclear-active particles of GCR.

Spontaneous fission of ^{238}U and ^{244}Pu in phosphates from pallasites

The estimation of values of the contribution in expected track density of three-prong track events from spontaneous fission of ^{238}U and ^{244}Pu in phosphates from pallasites at concentration of uranium ~ (50 - 100) x10^{-9} g/g and track density of spontaneous two-prong fission equal to ~10^5 - 10^6 cm^{-2} gives values which is not exceed ~10^{-2} of three-prong events on cm^2 of an analyzed surface of a crystal.

Induced by nuclear-active particles of GCR fission of heavy elements

The estimation of probability of background events of three-prong fission of heavy elements (Pb, Bi, Th and U), induced by primary (p, n) and secondary (n, p) nuclear-active components of GCR, is carried out on the base of following experimental data:

The fission rate of heavy elements on two fragments, induced by cosmic radiation, is received on the data of [8]. On depth up to ~100 g/cm^2 of the lunar soil matter the basic contribution is necessary on ^{232}Th. Since depth ~200 g/cm^2, the fission rate of ^{232}Th and ^{235}U become comparable, mainly at the expense of highly effective fission of ^{235}U under action of thermal neutrons.

- The induced fission rates of others (mainly Pb, Bi, Au) heavy elements appear on 4-5 orders of magnitude by lower.

- The deep variation of total induced fission rate under action of GCR on nuclei of heavy elements in comparison with the constant on depth of spontaneous fission rates of an isotope ^{238}U, allows to

estimate the rate of formation of three-prong cases of fission in volume of silicate crystals. These crystals simultaneously are the targets at GCR irradiation in cosmic space and the nuclear track detectors of fission fragments formed during the whole of each meteorite history.

- In estimations also was taken into account theoretically received [7] meanings of probability of three-prong fission events are depending significantly on value of a charge of the easiest fragment (Z_L). So at increase of Z_L from 6 up to 25 effective cross-section of three-prong fission in nuclear reaction (N + Au) decreases from 5 up to 0.08 mb, and for reaction (N + Th) from 15 up to 0.8 mb. There the energy of nitrogen ions equal to E_N = 1.5-2.5 MeV/amu).

The relation of effective cross-section values of fission on three and two fragments for the mentioned above nuclear reactions constitutes 10^{-3} - 10^{-4}.

Conclusions

On the basis of the carried out estimation of the values of contribution from various sources of fission of heavy element nuclei at an irradiation of meteorites in cosmic space, and also, starting from the received experimental meanings of track density three-prong (ρ_{3f}) and double-prong (ρ_{2f}) of fission of compound-nuclei of SHE (Z = 110) [1], the value of the relation probability of three-prong track events was determined: in comparison with the probability of three-prong fission of SHE nuclei contribution of all possible background sources is equal not higher ~ 10^{-3}.

The carried out quantitative estimation of expected volume track density of three-prong cases of SHE nuclei fission has shown, that in view of the probable contribution of all considered sources of a background at viewing not less (0.1-0.5) cm^3 of total volume of phosphate crystals from meteorites, in them it can be revealed from several up to several tens cases of three-prong fission of SHE nuclei.

For research most suitable are silicate minerals of phosphates – whitlokite and stenfildite, included in pallasite structure as large (up to ~ 0.5 mm) transparent crystals.

The viewing, detection and measurement of track parameters in the total volume of researched crystals can be carried out only by chemical etching with the help of TINT ("track in track") - technique. At that super-long (up to ~200 μm) tracks - channels, on which etching solution will penetrate in depth of crystal, is artificially formed in them by the high-energy (E ≥ 10 MeV/nucleon) Xe or U nuclei irradiation on the accelerator of heavy ions.

Thus, detection of three-prong fission cases in phosphate crystals of meteorites, the formation age of which makes ~ (4.45 - 4.55) b.y., will testify to registration of traces of SHE nuclei disintegration in the extraterrestrial matter.

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