ON THE PROBLEM OF SEARCH FOR SUPER-HEAVY ELEMENT TRACES IN THE METEORITES: PROBABILITY OF THEIR DISCOVERY BY THREE-PRONG TRACKS DUE TO NUCLEAR SPONTANEOUS FISSION. *L.L. Kashkarov[1], L.I. Kravets[2], G.V.Kalinina[1], G.P.Kniazeva[2] . [1] Vernadsky Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, 119991, Moscow, Russia* ugeochem@geochem.home.chg.ru . *[2] Joint Institute for Nuclear Research, Dubna, Russia.*

Introduction: Search and identification of super-heavy elements (SHE) of Z≥110 in a cosmic matter were carried out by observation in olivine crystals from meteorites pallasites of the anomalous-long chemically etchable tracks - traces of braking of high-energy trans-uranic SH-nuclei, contained in the galactic cosmic rays (GCR) [1-3]. Calibration of track lengths formed in olivine by the accelerated ^{238}U nuclei of ~30 and ~70 MeV/nucleon energy [4] indicate, that the maximum in a length distribution of specially annealed and then etched tracks for them is L = 230 ± 25 µm. On this base discovered in these investigations 11 very long (L ≥ 340 µm) tracks can be attributed to SH-nuclei.

Principally new approach to a problem of SHE search is based on registration of ternary spontaneous fission cases [5]. First experimental observation of three-prong fission tracks of SH nuclei were performed by Perelygin et al. [6]. The unique, rare events of ternary spontaneous fissions of the compound SHE nuclei $^{278}C_{110}$, formed at capture by $^{238}U_{92}$ nuclei of accelerated up to ~10 MeV/nucleon of $^{40}Ar_{18}$ ions, were observed at these experiments. From obtained results probability of SHE ternary fission in relation to fission on two fragments: ≤3×10^{-4} was determined. This value appears on three-four order of magnitude higher of ternary fission probability for ^{238}U nuclei [6,7].

In our report a number of issue concerning to probability of registration of three-prong fission fragment tracks in meteorite silicate crystals, enriched by actinides, are considered.

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

Spontaneous fission of ^{238}U and ^{244}Pu in meteoritic phosphates. The estimation of the contribution in expected three-prong track density due to spontaneous fission of ^{238}U and extinct ^{244}Pu in phosphates from meteorites gives the next of values: at concentration of uranium ~ $(50 - 100)\times10^{-9}$ g/g and track density of spontaneous two-prong fission equal to ~10^5 - 10^6 cm^{-2} the values of three-prong events on cm^2 of an analyzed surface of a crystal is not exceed ~10^{-2}.

Cosmic-ray induced fission of heavy elements. The estimation of probability of background events formation 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) 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 meteorite history. In estim ations 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 fission 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 under nitrogen ions energy of E_N = 1.5-2.5 MeV/amu. The relation of fission probability on three and two fragments for the mentioned above nuclear reactions equal to 10^{-3}-10^{-4}.

Some methodological remarks. It is need to observe several methodological characteristic properties as the sources of uncertainty and errors: (1) thermally un annealed VVH (Z≥30) cosmic-ray nuclei; (2) possible etching of track-like figures; (3) uncorrected annealing temperature of fission fragments; (4) tracks from the neutron-induced fission of U and Th isotopes; (5) formation of V-sharp tracks due to fragments from cosmic-ray spallation nuclear reactions.

Three types of cosmic-ray induced fission possibilities must be considered; (a) ^{235}U by neutrons (E≤1 Mev); (b, c) ^{238}U and ^{232}Th by neutrons (E = 1 – 100 MeV) and (E ≥ 100 MeV), accordingly. Experimentally determined proton-induced fission of U and Th as a function of a simulated lunar material depth [8] give possibility to derive corrections accounted with the depths, exposure ages, and heavy target elements (U, Th, Bi and Pb) contents in the samples under investigaton. For comparison and clarity in Table 1 the uranium concentrations and measured track densities of different origin in two main silicate minerals from pallasite meteorites are presented. The results of estimated corrections show that proton-induced fission is negligible and it makes a minor contribution even at a maximum flux of ~5 protons/cm^2·sec.

Conclusions: On the basis of the carried out estimation of the values of contribution from various sources of heavy element nuclei fission 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 false event sources is not higher ~10^{-3}.

The carried out quantitative estimation of expected value of 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 false events, at viewing not less ~0.1 cm^3 of the total volume phosphate crystals from meteorites, it can be revealed up to several cases of three-prong track events related to SHE nuclei fission. Thus, detection of three-prong fission cases in phosphate crystals from meteorites, the formation age of which makes ~ (4.45 - 4.55) by, will testify to registration of traces of SHE nuclei fission in the early Solar system matter.

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Table 1. Tracks of different origin, that can be measured in the main silicate minerals from pallasites.

Mineral	U Content, ppb	Track density, cm^{-2} *				
		^{238}U (4.6 ·by)	Cosmic § ray	Cosmic-ray induced fission ∇		
				Protons E>100 MeV	Neutrons E<1 MeV	Neutrons E~(1-100) MeV
Olivine	0.1 - 1	10^3 - 10^4	(1-10)×10^5	(1-2)×10^{-1}	(0.5-1)×10^{-1}	(1.5-3)×10^{-1}
Phosphate	50 - 100	(0.5–1)×10^6	(2-20)×10^5	~10^3	~5×10^3	(1–2)×10^4

∗ - For a cosmic-ray exposure age of 100 Myr. § - Track production rate in depth of ~200 g/cm^2 [8]. ∇ - Accounted for the heavy target elements U, Th, Bi, Pb.