ON SEARCH AND IDENTIFICATION OF TRACK DUE TO THE SPONTANEOUS FISSION OF SUPER HEAVY ELEMENT NUCLEI (Z≥110) IN EXTRATERRESTRIAL PHOSPHATE CRYSTALS

V.P. Perelygin1,  Yu.V. Bondar2,  L.L. Kashkarov3, L.I. Kravets1,  R. Brandt4,  W.Susinger4,  P.Vater4,  and G.P.Kniazeva1

1Joint Institute for Nuclear Research, Dubna, Russia, (pergam@cv.jinr.ru), 2 Institute of Environmental Geochemistry, Kiev 03142, Ukraine, 3 V.I.Vernadsky Institute of Geochemistry and Analytical Chemistry RAS, Moscow, Russia
4Philipps University, Kernchemie, Marburg, Germany

Introduction. The existence of relatively stable super heavy elements (SHE) in Nature was predicted theoretically at the midst of the sixties [1]. Basing on nuclear shell model it was estimated, that double magic nuclei with atomic number 110 ≤ Z ≤ 114 and neutron number N = 184 can possess the life time at ≥ 10^3 up to 10^9 years. Thus, these elements, similarly to Th and U, can survive in the Earth and meteorites since formation of Solar system.

The experimental attempts to discover such long-lived SHE nuclei with the life time ≥ 2×10^8 y in natural samples undertaken during the late sixties up to end of seventies provided some evidence of their existence in a number of both terrestrial samples and meteorites. These experiments were done by the investigation of alpha radioactivity and spontaneous fission activity, which exceeds significantly the effect due to the spontaneous fission of 238U nuclide. Still no decisive information on the existence of SHE in the nature was obtained.

In the fossil track study of olivines annealed at 430°C during 32 h we found the 250 μm – long track which could not be attributed to Th-U nuclei at any orientation in the crystal lattice [2,3]. Now we can set an upper limit of the SH (Z≥110) nuclei abundance at the level N_Z ≥ 110 / N_{Th, U} ≤ (1+3)·10^{-3}. Our goal is to obtain the final, necessary and sufficient proofs of the existence of SH nuclei in Galactic matter.

A new method for investigation of the short-lived super-heavy (SH) nuclei component of galactic cosmic-ray (GCR) nuclei (Z=50–92) has been developed. It depends on the ability of extraterrestrial silicate crystals (olivine) to register and store during many million years the tracks due to cosmic-ray nuclei with Z≥22. Our approach bases on the partial annealing of both “fossil” tracks and the tracks due to accelerated Kr, Xe, Au, Pb and U ions, and on the chemical etching of total volume track length of the cosmic-ray nucle. These freshly-formed nuclei with Z ≥ 36 up to Z≈110 and even heavier ones are accelerated with intense electromagnetic field of exploding neutron star up to energy 10^6 GeV per nucleon. These nuclei can reach the Solar system in time as short as 10^7 years and produce the “latent” very long track in no conducting crystals.

Thus, we can look for the SHE nuclei with the life time ≥ 10^7 y in extraterrestrial crystals, when they were exposed for many million years at the surface of meteorites and Moon regolith. The other possibility to identify SHE in Nature is to search for the tracks in the crystals (phosphate) due to spontaneous fission of Z ≥ 110 nuclei which produce 2-prong and 3-prong fission fragment tracks and differ significantly from the tracks due to the spontaneous fission of 238U and 244Pu nuclei. The extraterrestrial phosphate crystal (moon and meteoric origin) shall be investigated in the future studies, because these crystals start to register the fission fragment tracks about 4.2–4.3 billion years after cooling down a parent body of these extraterrestrial objects. Such a nuclei of SHE can survive in the extraterrestrial rocks crystal and produce the tracks due to spontaneous fission if their life time is more than 5×10^7 years.

Registration of most heavy cosmic-ray nuclei There are two approaches to the
problem of registration of ultraheavy ($Z \geq 36$) Galactic cosmic-ray nuclei. The traditional ways for investigation of ultraheavy nuclei of Galactic cosmic rays were based on direct registration of these nuclei in the outer space with big stacks of nuclear emulsions and/or plastic track detectors.

The other way of Galactic cosmic ray investigations was based on the ability of non-conducting meteoritic crystals—pyroxenes, olivine, feldspars and phosphates to register and store for many tens and hundreds million years the tracks due to the nuclei with $Z \geq \ldots$ But on obtaining quantitative information on the charge and energy spectra of ultraheavy cosmic-ray nuclei based on a fossil track study in extraterrestrial crystals we meet a number of methodological problems, such as very high background due to Fe group nuclei, $(10^{10} - 10^{12}$ tracks per cm$^2$). Another problem is connected with partial annealing of the track in silicate crystals under outer space conditions, which does not allow us to compare directly the etchable track length of fossil tracks and the “fresh” tracks that are calibration samples of the same crystals with accelerated heavy ions ($Z = 20 – 92$). That is why of some groups attempted to make at the end of the sixties and beginning of the seventies investigate ions of the heaviest component in galactic cosmic-ray nuclei by the track study in meteoritic and Moon crystals, which yielded only qualitative results in the region of cosmic-ray nuclei with $Z > 83$ (see for review [4]).

Spontaneous fission of the nuclei with $Z \geq 110$. The other possibility is the search and identification of fossil tracks due to the spontaneous fission of the nuclei with $Z \geq 110$ in extraterrestrial phosphate crystals. There are two possibilities:

1. The annealing behavior of spontaneous fission fragment tracks differs drastically in phosphates for actinides and SHE. The proper annealing (for instance, at 703 K during 32 h for Marjalahti whitlockite) provide the separation of fission fragment tracks due to $^{238}$U-$^{244}$Pu spontaneous fission and due to spontaneous fission of to the nuclei with $Z \geq 110$ in VETL by a factor 2. The fossil track spectra must be compared with the track by thermal neutron-induced fission of $^{235}$U nuclei in the same crystals annealed at the same conditions. Such tracks shall provide some proofs of the existence of the spontaneous fission of the nuclei with $Z \geq 110$.

2. The probability of ternary spontaneous fission of the nuclei with $Z = 110 – 114$ as compared with binary fission is estimated to be $10^{-3} – 10^{-4}$. For actinide nuclei the ratio of $N_{3f}/N_{2f}$ is $\leq 10^{-7}$. These 3-prong tracks also shall have the mean length 20% greater than binary tracks due to spontaneous fission of actinide nuclei. Thus, the observation and measurements of such 3-prong spontaneous fission tracks in the volume of phosphate crystals shall provide the unambiguous proofs of SHE nuclei existence in Solar system.

In both cases it is necessary to reveal the tracks of spontaneous fission under polished surface of these crystals. For such a study we shall use the accelerated heavy ions with $Z \geq 30$ and an energy of $\geq 10$ MeV per nucleon.

The identification of tracks due to spontaneous fission of SHE nuclei in extraterrestrial phosphate crystals in the presence of a significant background due to spontaneous fission of $^{238}$U and also $^{244}$Pu in extraterrestrial samples by “Track in Track” (TINT) technique by revealing of 3-prong spontaneous fission tracks and by controlled annealing of these crystals (case of 2-prong events). In our study we shall choose whitlocite and stanfildite crystals from meteorites Marjalahti, Lipovsky Khutor, Omolon and phosphates from Luna-16 and Luna-24 probes.

The present work has been performed under the Russian Foundation of Basic Research (grant No 01-02-16410).