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Nuclei charge identification for the galactic cosmic ray transuranic elements by the chemically etching tracks in the pallasite olivine crystals

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Introduction

In the framework of the project OLYMPIA [*Ginzburg et al*., 2005] basic problem for the heavy and super heavy (Z > 70) galactic cosmic ray (GCR) nuclei of the charge determination are considered. The method of search and the track parameters measuring in the automatically regime with help of the PAVICOM system [*Feinberg et al*., 2004; *Alexandrov et al*., 2008] was utilized. For this purpose chemically etched lengths and track-etch rate of the not-annealed traces of the braking nuclei in the olivine crystals from the Marjalahti and the Eagle Station pallasites were used. The data of the calibration experiments, performed for the accelerated nuclei of ^{36}Kr, ^{54}Xe, ^{79}Au and ^{92}U, and the theoretically accounted by the programs of SRIM2006 и GEANT4 etched track length of the braking nuclei were used in the identification of their charges [*Kashkarov et al*., 2008; *Alexandrov et al*., 2009]. Primarily, in the article one of the possible method of the GCR transuranic elements charge identification, based on approximation of the geometry and dynamical parameters, determined for the nuclei of charge 82 < Z < 92 [*Alexandrov et al*., 2008] is presented.

Method of the GCR superheavy nuclei charge identification

For the GCR super heavy (Z > 50) nuclei charge determination the two main parameters of the tracks, etched in the olivine crystals from the Marjalahti and the Eagle Station pallasites, were used: the geometry parameter – measuring track length (L) and the dynamical parameter – track etching rate (V_{TR} = L/t, where t – time interval of etching) [*Kashkarov et al*., 2008; *Александров и др.,* 2009].

The chosen methodology is based on precise measurements of the nucleus track parameters in the course of the step-by-step chemical etching of the olivine crystals. Parameters of tracks are traced and recorded by a modern, high-precision, completely automated measuring system PAVICOM [*Feinberg et al*., 2004; *Alexandrov et al*., 2008]. Recognizing, that the zone of the crystal structure disordering, that is corresponding to chemical etching, is in an interval of the nucleus energy E_{MAX} - E_{MIN} , where the specific losses of energy $(dE/dx)_{EL}$ exceed the critical value of 18±2 MeV·mg^{-1}·cm^{2}, the track length with increase of a nuclei charge correspondly is increases.

Calibration of track parameters in the olivine crystals from Marjalahti pallasite was performed on UNILAC accelerator in Darmstadt, Germany. The ^{36}Kr, ^{54}Xe, ^{79}Au and ^{92}U accelerated nucleus beams were used. On base of obtained track-length distributions the L_{max} , corresponding to the energy of ions, were determined. Within the limits of measurement errors these track lengths coincides with the values accounted by the SRIM2006 and GEANT4 computing programs. The track etching velocity (V_{TR}) for the nuclei of E_{max} = 11.4 MeV·nucl^{-1} varies in limits (5÷ 20) μm·hour^{-1}. The last have been carried out using additionally the data of the olivine crystals irradiation by the accelerated U nuclei of energy 150 MeV·nucl^{-1} [*Perron and Maury*, 1986].

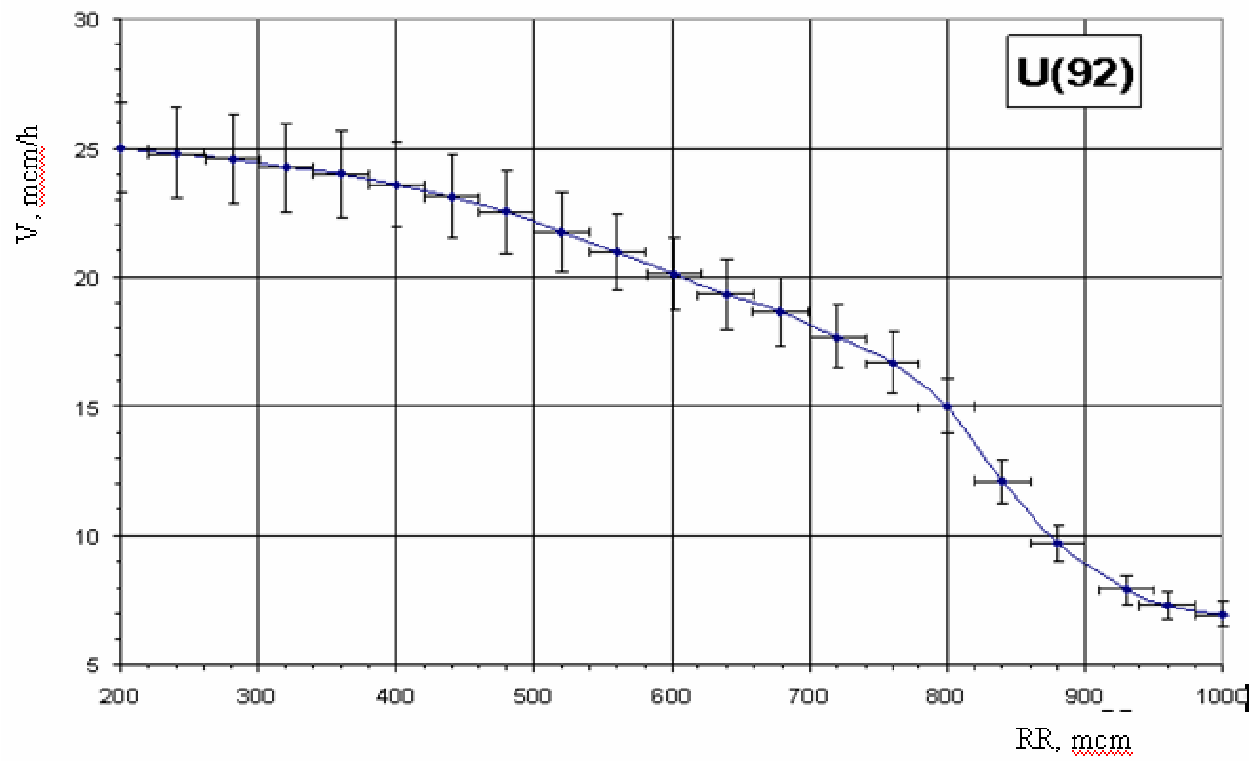

Fig. 1. The track-etching rate (V_{TR}) *vs* residual range (RR) of the U nuclei in the olivine crystals from the Marjalahti pallasite [*Perron and Maury*, 1986].

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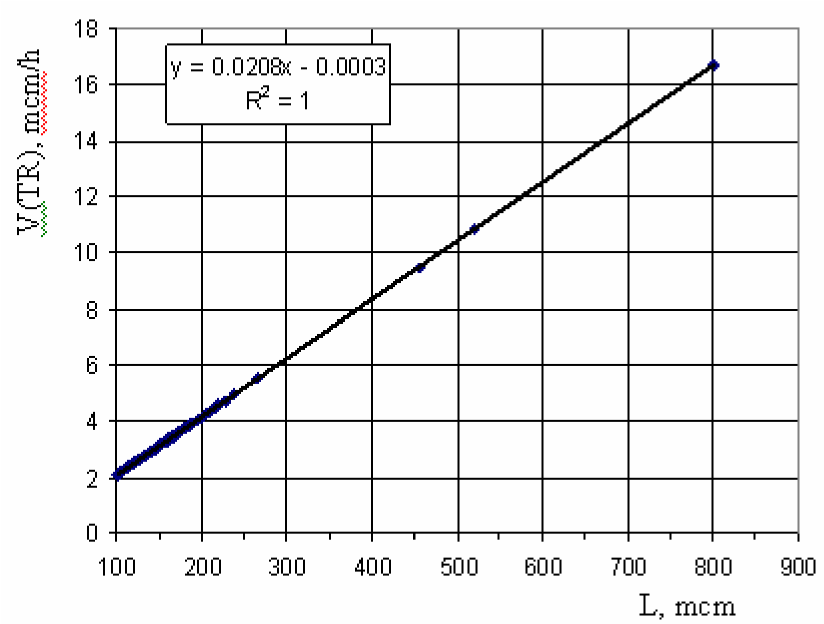

Fig. 2. (V_{TR}) -L relationship for the GCR nuclei of charge (Z > 55) in the olivine crystals from the Marjalahti pallasite.

As it seen from the graph of Figure 2, relationship between of V_{TR} and L for the GCR nuclei of charge (Z > 55) in the olivine crystals from the Marjalahti pallasite is strongly linear autocorrelation (correlation coefficient $R^2 = 1$) in the very wide range of the etched track-lengths, from ~ 100 µm up to ~ 800 µm. Respondent to this track-length interval nucleus charge values are in interval of Z ~ (50 - 92).

Distribution of the identified GCR ultra-heavy (Z > 80) nuclei charge values in comparison with their residual range (RR_{BASE}) are shown in Figure 3. The accounted parameters of these linear order dependence are presented in Table.

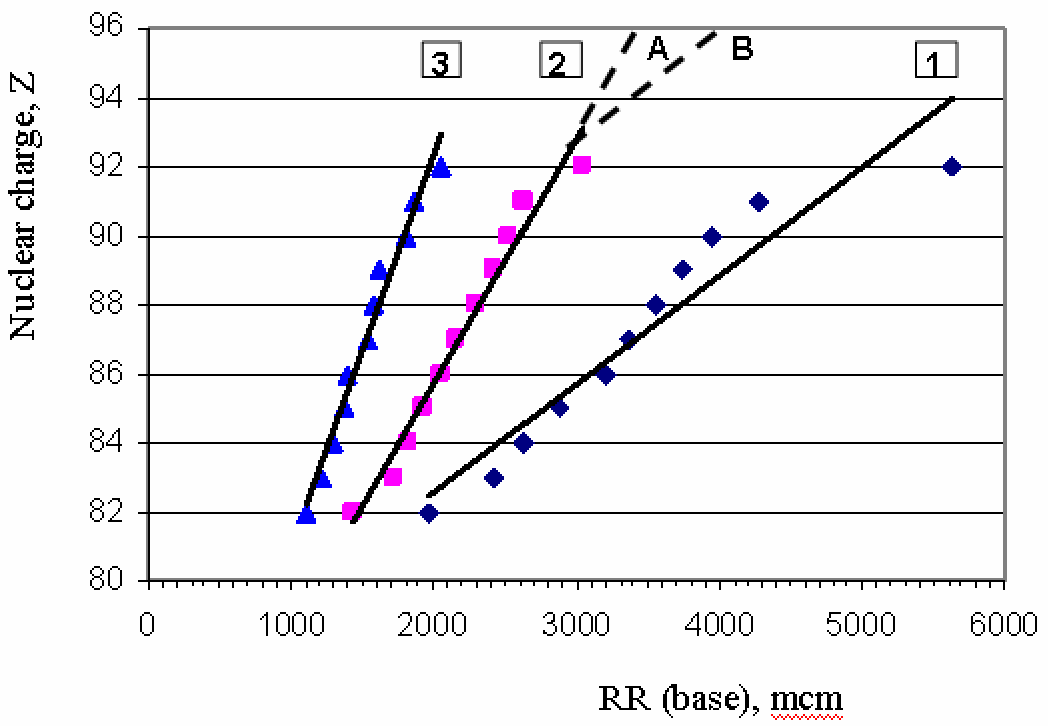

Fig. 3. Theoretically accounted residual range (RR_{BASE})-dependence of the identified GCR ultra-heavy (Z > 80) nuclei charge values in olivine crystals from the Marjalahti pallasite. The approximated straight lines (1, 2 and 3) are related to the points, that are resulted for $(dE/dx)_{CRIT}$ equal to 16, 18 и 20 $MeV{\cdot}mg^{-1}{\cdot}cm^2$, correspondingly. Dotted lines (A) and (B) indicate two possible variants of the relationship $Z = f(RR_{OCH})$ in the charge region of (Z > 92) in the case of linear (A) and not-linear (B) dependence.

It is need note the determined by used up to day method of Z values identification in a majority of cases gives only any lowered (by 2-3 charge units) Z-values in comparison to the true nucleus charge meaning.

Table. The correlation parameters in according of identified GCR nuclei with the charge of ($82 \leq Z \leq 92$) to the theoretically estimated values of their residual range RR_{BASE} at various $(dE/dx)_{CRIT}$ in the olivine crystal from the Marjalahti pallasite.

$(dE/dx)_{CRIT}$, $MeV{\cdot}mg^{-1}{\cdot}cm^2$	$Z = f(RR_{BASE})$	$R^{2\,(*)}$
16	$Z = 0.0032{\cdot}RR_{OCH} + 76.2$	0.9077
18	$Z = 0.0071{\cdot}RR_{OCH} + 71.411$	0.9713
20	$Z = 0.0112{\cdot}RR_{OCH} + 69.75$	0.9772

(*) R^2 – correlation coefficient

Results.

Detailed consideration of the dynamic and geometrical parameters for the near of 2000, revealed up to this time in the 120 olivine crystals, tracks with the etched and registered length L in interval of 50-500 µm in comparison to the data of the calibration experiments have been performed. It is obtained satisfactory fit of our nuclei charge statistical distribution with the data of cosmic satellite apparatuses investigation [*Shapiro,and Silberberg,* 1974; *Israel,* 1981].

From $thL_{TR,U}$ and $V_{TR,Z} > V_{TR,U}$, that indicated on their formation by the stopping transuranic (Z > 92) nuclei, are considered. On the base of the theoretical computation for the total etched track-length values and extrapolation of the track-parameters in the nuclei charge region up to Z ≈ 110 the quantitative estimation for the alone, observed in the olivine crystal from the Eagle Station pallasite, super-long track are briefly considered.

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