LEAD AND URANIUM GROUP ABUNDANCES IN COSMIC RAYS

Yadav, J.S. and Perelygin V.P.*
Tata Institute of Fundamental Research, Bombay 400005, India

*Joint Institute for Nuclear Research, Dubna, Moscow, USSR.

ABSTRACT

In the light of Ariel-VI and HEAO-3 ultra heavy cosmic ray experiment results, the importance of Lead and Uranium group abundances in cosmic rays is discussed in understanding their evolution and propagation. The electronic detectors can provide good charge resolution but poor data statistics. The plastic detectors can provide somewhat better statistics but charge resolution deteriorates. The extraterrestrial crystals can provide good statistics but with poor charge resolution. Recent studies of extraterrestrial crystals regarding their calibration to accelerated Uranium ion beam and track etch kinetics are discussed in this paper and it is hoped that a charge resolution of two charge units can be achieved provided an additional parameter is taken into account. The prospects to study abundances of Lead group, Uranium group and superheavy element in extraterrestrial crystals are discussed, and usefulness of these studies in the light of studies with electronic and plastic detectors is assessed.

1. Introduction. The high energy resolution UH experiments Ariel-VI and HEAO-3 have given the following important conclusions [1,2]: (a) There is no strong evidence for r-process dominance in the cosmic ray source in the charge region $Z < 60$. In this charge region the cosmic ray source composition looks like that of the solar system with a first ionization potential bais or possible some s-process enhancement. (b) The lead group abundance data appear to show r-process dominance in this charge region (Peak at platinum), and (c) The abundances of actinides is much lower than measured in earlier experiments [3,4,5].

The HEAO-3 results of actinide abundances are quite consistent with a source with solar system like composition [1]. However, with the precision of the results based on one possible actinide event (or three if HEAO-3 and Ariel-VI data is combined) one can not exclude substantial r-process enrichment or deficiency in cosmic ray source. Thus one needs an experiment with larger exposure factor to study actinide abundances. Further, the study of actinide abundances is important as it gives clear indication of r-process contribution. The s-process terminates at Bismuth (z = 83). The main problem in the study of actinide abundance is their very low flux. Following table gives the measured event rate of actinides and superheavy elements for a detector with exposure factor like HEAO-3.

Table 1 : Event Rate in a 5m^2 sr Detector

	Actinide group	Superheavy elements
From HEAO-3 data	2/ year	-
From extraterrestrial crystal data*	2/ year	10^{-3}/ year**

* These rates are calculated with atleast 10% probability that tracks are completely inside the volume of the crystal revealed successfully. This also takes care of fragmentation of actinides in crystals.

** This is on the basis if observed 3 very long tracks are due to superheavy elements.

It is clear from the above table that one needs a detector with much larger exposure factor than combined HEAO-3 and Ariel-VI detectors to study actinide abundances. Further study of superheavy elements seems to be out of experimental reach at least at present. However, the abundances of actinides and superheavy elements can be studied in extraterrestrial crystals due to their very long exposure time provided their charge resolution is improved. Now we shall describe recent studies regarding track identification in crystals and assess the usefulness of studying UH cosmic ray abundances in extraterrestrial crystals.

2. Results and Discussion. In the recent past, olivine crystal has been exposed to accelerated Uranium beam and the track etch response has been studied[6]. In the further development, track etch kinetics in crystals has been described and the effect of etching time on track etch response and on volume etched track length (VETL) (track identifying parameter) is studied[7]. The VETL variation with etching time is shown in Fig. 1, for Uranium as well as superheavy element tracks.

Above study shows that a charge resolution of two charge unit can be achieved in crystals. However, the exposure of extraterrestrial crystals in adverse environment (not known exactly) will further deteriorate charge resolution [5]. Thus one can expect a charge resolution 3-4 charge units. Let us check the feasibility of extracting useful information regarding UH cosmic ray abundances from studies in extraterrestrial crystals with such charge resolution.

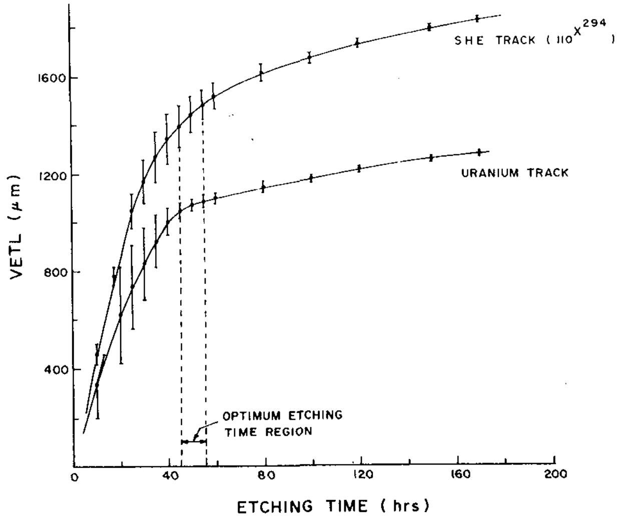

Fig.1 The VETL variation with etching time for Uranium as well as superheavy element tracks.

If we look at the abundances of UH nuclei in cosmic rays there are natural gaps between Lead and Uranium groups and between Uranium group and Superheavy elements. The elements in the charge region $84 < Z < 89$ have half lives that are typically less than a day and hence should be absent in the cosmic rays. Similarly in actinide group only Thorium, Uranium, Plutonium and Curium nuclei have half lines sufficiently large to allow them to survive in cosmic rays. The superheavy nuclei stability island[8] most probably starts at $Z > 110$. Thus it is quite feasible to extract useful informations about abundances of Lead group, Uranium group and Superheavy elements in cosmic rays from UH track studies in extraterrestrial crystals.

Further UH studies in extraterrestrial crystals will provide actinide abundances averaged over millions of years and hence can pin-point any substantial change in actinide abundances over this period. This can indicate continuous r-process in cosmic ray source or solar system like composition of cosmic ray source where r-process is stopped for the last few billions of years.

References

1. Fowler, P.H. et al. (1981), Nature, 291, 45.
2. Israel, M.H., Composition and Origin of Cosmic Rays (1983) Ed. M.M. Shapiro, NATO ASI series, 47.
3. Fowler, P.H. et al. (1977), 15th ICRC, 11, 165.
4. Perelygin, V.P. et al. (1977), Nucl. Track, 1, 199.
5. Shirk, E.K. and Price, P.B., (1978), Astrophys. J., 220, 719.
6. Perron, C.,(1984), Nature, 310, 397.
7. Yadav, J.S. et al. (1985), sent for publiccation in Nucl. Track.
8. Trautmann, N. (1981), Intern. Conf. on 'Actinides 81'.