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Shock wave fractionated noble gases in the early solar system

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Abstract. Many processes in the active star-forming regions are accompanied by strong shock waves, in acceleration by which the nuclear-active particles form the power-law energy spectrum of high rigidity: $F(> E_0) \sim E^{\gamma}$, with the spectral index $\gamma \leq$ 1.5–2. It must affect the production rates of spallogenic components of the isotopes, whose excitation functions depend on the shape of the energy spectrum of radiation. Thus, the isotopic signatures formed in the conditions of the strong shock wave propagation must be different from those formed in the calm environment. The early solar system incorporated all the presumed processes of the star-forming stage, so that its matter had to conserve such isotopic anomalies.

In previous works [1] the shock wave effects in generation of extinct radionu-clides and light elements Li, Be and B were considered. In the report some results for their evidence in the noble gas signatures are presented. Modelling the Kr isotope generation in spallation of Rb, Sr, Y and Zr with the nuclear-active particles, the energy spectrum of which was variable in the range of γ= 1.1–6.0, shows the different pace of growth of abundances of the dif-ferent Kr isotopes with decreasing . It leads to the quite diverse behaviour of the various Kr isotope ratios: the ^{78,80}Kr/^{83}Kr ratios increase, and the ^{82,84,86} Kr/^{83}Kr ratios decrease for the smaller γ. According to such criteria, for instance, the isotopically heavier SEP-Kr in the lunar ilmenites was pro-duced with the accelerated particles of the more rigid energy spectrum ($\gamma \sim 2$) in comparison with the SW-Kr.

Another important feature of the shock wave acceleration of particles is the enrichment of their specrtum with heavier ions in proportion to A/Z. Clearly, the shock wave fractionation of the noble gases, favouring the heavier isotopes, had to be inevitable. Such a fractionation depends on timing episodes of shock wave acceleration: after the n-th act of the ion acceleration their fractionation is proportional to (A/Z)^n, and the isotopic ratio of i and j isotopes is proportional to $(A_i/A_j)^n$. Therefore, the extent of processing the matter of the protosolar nebula by shock waves determined the state of the matter fractionation. Thus, the consideration of the 9-isotopic system of Xe demonstrates that the five-fold shock wave fractionated Xe of the solar type matches the Xe of the Mars and Earth atmospheres. Some astrophysical inferences are discussed.

[1] G. K. Ustinova. Solar System Research 29, 298-308, 1995; 30, 429-439, 1996.