ON POSSIBLE Mn-53 HETEROGENEITY IN THE EARLY SOLAR SYSTEM;

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There are shown the effects of influence of shock wave propagation on the energy spectrum of accelerated particles that lead to different production rates of radionuclides, in particular, Mn-53, on small scales in the early solar system.

Search for evidence for extinct Mn-53 has stimulated investigations of Cr isotope anomalies in meteorites. The linear correlation between the magnitude of the Cr-53* excesses and the Mn/Cr ratio that unambiguously proves the in situ decay of Mn-53 has been detected, really, in different mineral phases of some carbonaceous and enstatite chondrites, primitive achondrites, pallasites and iron meteorites /1-5, etc./. However, the data on the Cr-53* excess rarely define a single linear array on a Mn-53 -Cr-52 evolution diagram even for meteorites of the same chemical group. A clear isochron with Mn-53/Mn-55 = $(4.4\pm1.0)\cdot10^{-5}$ (in range of ~2.4 to $\sim9 \cdot10^{-5}$) is observed for CAI of the Allende C3-chondrite /1/ while the data for the Murchison C2- and Orgueil C1-chondrites fall much lower corresponding rather to Mn-53/Mn-55 $< 2\cdot10^{-5}$ /2/. In the case of iron meteorites it ranges from $<5\cdot10^{-8}$ to $<5\cdot10^{-5}$ /3/.

If the initial Cr and Mn distribution in the early solar system was homogeneous, then the different magnitude of the excess of the radiogenic Cr-53* in the mineral phases was conditioned by the different time of their solidification. Thus, using Mn-53 as a chronometer, one could build a time scale for evolution of the matter in the early solar system during, at least, n$\cdot$10 Myr.

Unfortunately, the high precision investigations of Cr isotope composition in meteorites revealed essential variations of it, the correlation effects for Cr-54 and Cr-53 to be detected too /2,5,6/. It clearly testifies to initial Cr heterogeneity in the early solar system, although, partly, it could be explained by Cr diffusion between different mineral phases /5/, fractionation /2,6/ or even terrestrial weathering /6/.

The authors of practically all the cited works also pointed out possible initial heterogeneity of Mn-53 in the early solar system. This point of view attracts attention in the light of the described earlier possible mechanism of forming isotopic heterogeneities on the primordial stage of evolution of the matter /7,8/. The question is about heterogeneity of the conditions for isotope production during shock wave propagations (e.g., in expanding shells of a supernova or in collisions of strong protosolar winds with matter of the accretion disc) because then the energy spectrum of accelerated particles becomes more rigid /9/; therefore, their fluxes at high energies considerably increase, and the statistically weighted cross sections of many isotopes, whose excitation functions are sensitive to the form of the energy spectrum of particles, change too. Whereas index γ of the solar cosmic ray spectrum can reach 6, and it of the galactic cosmic ray spectrum equals to 2.5, but during the passage of
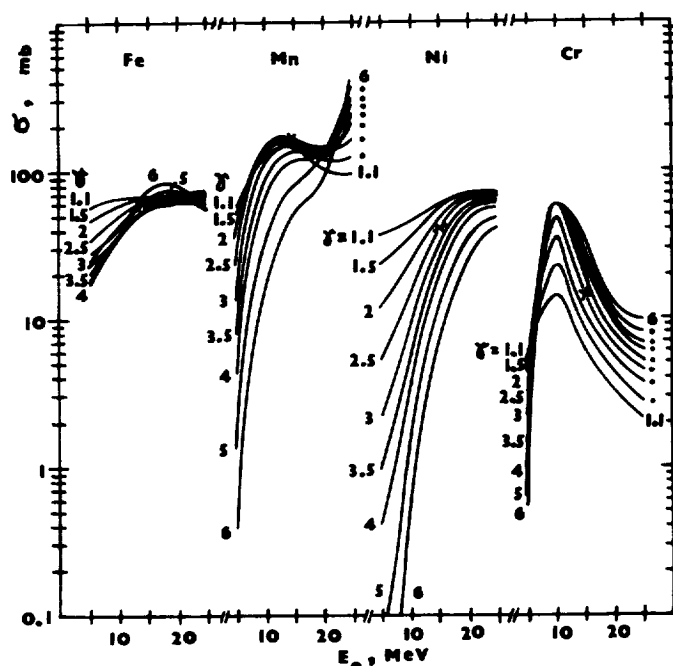
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Fig.1

shock waves it can decrease down to 1.5-2 /10/. The observed turbulence of neutral gas in the molecular clouds surrounding supernovas can even form the spectrum of particles with $\gamma \sim 1$ /11/. It is shown in /7/ that with changing γ from 1.1 to 6 the variation of integral flux of protons above the cut-off energy E_0 of the spectrum amounts to 6 orders of magnitude. Possible variations of the statistically-weighted (according to the energy spectrum of protons) cross sections of Mn-53 production on Fe, Mn, Ni and Cr in dependence on E_0 for different γ (figures on the plot) are demonstrated in Fig.1. The values of the cross sections corresponding to some average irradiation conditions in the early solar system are marked by crosses /7,8/. The ratios Mn-53/Mn-55 and Cr-53*/Cr-52 depending on E_0 for different γ are presented in Fig.2. It is seen that these ratios formed in conditions of shock wave propagation can vary by ~ 7 orders of magnitude that virtually corresponds to the measured range of them in meteorites. In the average irradiation conditions Mn-53/Mn-55 = $1.00 \cdot 10^{-4}$ is obtained (a cross on the plot) that is in accordance with its maximum measured values in the refractory CAI minerals. In the minerals with much lower solidification time ($\lesssim 1000K$) the measured values of this ratio are decreased by 2-3 orders of magnitude. Apparently, those minerals were condenced in calmer (and colder) regions of the early solar system where due to the softness of the particle spectra ($\gamma \gtrsim 4$) smaller amounts of Mn-53 were produced.

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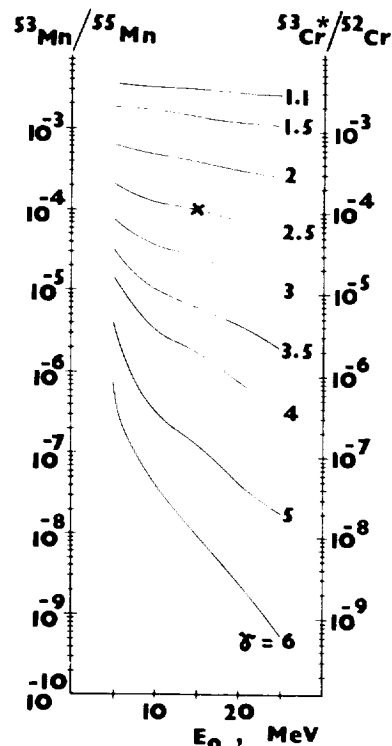
Fig.2