ON THE CONTRIBUTION OF PRIMARY GCR-PARTICLES TO THE PRODUCTION OF COSMOGENIC NUCLIDES IN METEORITES

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While for lunar irradiation conditions three methodologically different models exist which successfully describe the depth dependent production of cosmogenic nuclides /1-3/ and which are also in agreement with terrestrial thick target simulation experiments /4,5/, model calculations of the production of cosmogenic nuclides in meteorites /e.g.6-8/ still are not satisfactory. The latter show severe shortcomings mainly due to a lack of knowledge about the depth and size dependence of the built-up of secondary GCR-particles. Moreover, some of the existing models cannot be extended to small meteorite sizes, they exhibit logical contradictions when approaching the limiting case of $R \longrightarrow 0$. One way to overcome the difficulties of these model calculations is to strictly differentiate between the various contributions to the production of cosmogenic nuclides according to their origins and processes involved and then to investigate each contribution separately. So, the production rate P of a cosmogenic nuclide at depth d inside a meteorite of radius R is divided into three parts:

$$P(d,R)=P_{SCR}(d,R) + P_{GCR,prim}(d,R) + P_{GCR,sec}(d,R)$$

with P_{SCR}, $P_{GCR,prim}$ and $P_{GCR,sec}$ being the production by solar cosmic rays, by primary galactic particles and by secondary galactic particles, respectively. The contribution of SCR-secondaries is negligible because of the relatively low energies of primary solar particles. Each partial production rate P_x is given by

$$P_x(d,R) = \sum N_i \cdot \int \sigma_x(E) \cdot \Phi_x(d,R,E)\, dE,$$

with N_i being the density of target atoms of element i, $\Phi_x(d,R,E)$ the respective particle flux and $\sigma_x(E)$ the excitation function for the nuclear reaction involved. The $\Phi_{GCR,sec}(d,R)$ are almost unknown up to now. They might be evaluated from terrestrial simulation experiments or by calculations using high energy transport codes. The $\Phi_{SCR}(d,R)$ and the $\Phi_{GCR,prim}(d,R)$ can be calculated simply taking into account the energy loss and the attenuation of the primary particles.

P_{SCR} can be calculated with good "a priori" accuracy from the thin target cross sections and the depth dependent SCR-fluxes for lunar /9/ and meteoritic irradiation conditions /10/. Also $P_{GCR,prim}$ can be calculated provided the respective cross sections are available. Generally the accuracy

of all these calculations is determined by the reliability of the excitation functions used. During the last years we have performed a systematic investigation of thin target excitation functions for cosmochemically relevant p- and α-induced reactions mainly for the evaluation of P_{SCR} /e.g.11,12/. In this work, we present 28 newly measured excitation functions for the production of radionuclides $44 \leq A \leq 60$ by p-induced reactions on iron and nickel in the energy range 80 to 200 MeV. For this energy range up to now only very few and partially contradictory experimental data were at hand, so that often theoretical estimates of unknown excitation functions had been used in the past for model calculations of the interaction of cosmic rays with dense matter. Here our new data allow to test the reliability of such estimates and to point out the limits of today's a priori calculations of cross sections for cosmochemical applications.

Then, on the basis of the new consistent set of excitation functions model calculations for the depth dependent production of cosmogenic nuclides in small meteorites ($R \leq 100$ g/cm^2) by galactic primaries are presented. The sensitivities of these production rates to changes in the source spectra, as well as to individual energy groups is discussed. In particular, the calculations allow to determine the limits of GCR-production rates for small meteorites even if R approaches Zero. Comparing model calculations for P_{SCR} /10/ and $P_{GCR,prim}$ with experimental results of cosmogenic nuclides in meteorites, first estimates of the contribution of secondary GCR-particles in small meteorites are given.

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