COSMIC-RAY-PRODUCED COBALT-60 IN CHONDrites.
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In unfolding the cosmic-ray exposure history of a meteorite, it is best if a variety of cosmogenic products (tracks and nuclides) with different production profiles are used. Neutron-capture reactions have production rates which vary considerably with sample depth and meteorite size [1] and their production profiles are very different from those for tracks or spallogenic nuclides. In large meteorites, neutron-capture reactions are the main sources of certain cosmogenic nuclides, such as $^{36}$Cl, $^{59}$Ni, and $^{60}$Co [1]. Recently, the cosmic-ray-produced radionuclide $^{60}$Co, made via the $^{59}$Co(n,y)$^{60}$Co reaction, have been very useful in unfolding the cosmic-ray exposure record of the large Jilin (Kirin) chondrite [2,3].

Eberhardt et al. [1] have reported the production rates for several neutron-capture reactions in meteorites. Recently, we have calculated the fluxes of low-energy neutrons as a function of depth in spherical meteoroids of various radii [4] and reported preliminary results for the production of $^{59}$Ni and $^{60}$Co via (n,y) reactions [5]. The relative neutron source strengths and neutron-production-versus-depth profiles were estimated using calculated $^3$H production rates and the absolute source strengths were normalized to a semi-infinite plane value of 14.1 neutrons/cm$^2$ s [6]. The energy distribution of the source neutrons and the neutron-transport calculations using the ANISN code were similar to those used for the moon [7,8]. The calculated spectra of low-energy neutrons showed considerable variations from a $1/E^2$ shape for meteorites with $R < 150$ g/cm$^2$, especially near the surface [4]. We also confirmed the results of [1] that the production profiles of $^{59}$Ni and $^{60}$Co are different in the same meteorite [5].

Our calculated production rates of $^{60}$Co as a function in depth in spherical L-chondrites of various radii are shown in Fig. 1 as solid or dashed lines. Also shown is a calculated lunar curve [9], normalized to our source strength, and the calculated $^{60}$Co rates of [1]. In chondrites with $R < 50$ g/cm$^2$, the $^{60}$Co rates are less than 1 atom/min/g-Co. The maximum production rate probably is slightly above 300 atoms/min/g-Co near the centers of chondrites with radii of 200-300 g/cm$^2$. The production profiles for large radii are approaching that for the moon.

Our calculated $^{60}$Co production profiles are similar to those of Eberhardt et al. [1]. Their production rates at the surface were near zero, while our largest rate at the surface is 13 atoms/min/g-Co for $R = 300$ and 600 g/cm$^2$. Their maximum rate is about 420 atoms/min/g-Co, about 30-35% above our maximum rate. Part of this difference is due to the absolute source strengths used, as their semi-infinite medium value is about 13% greater than ours. Their profile for 150 cm (about 525 g/cm$^2$) decreases from the maximum rate to the central rate much slower than our profile for 600 g/cm$^2$ (a factor of about 1.6 versus our decrease of 2.57).

The $^{60}$Co activities measured in the Jilin (Kirin) meteorite, which had a radius of about 75 cm, ranged from 53 to 237 dpm/kg [3] (about 62-280 dpm/g-Co), in good agreement with the magnitudes of our calculated production rates. An activity of 62 dpm/g-Co would correspond to a pre-atmospheric
depth of about 20 g/cm² and the highest activities would be made at depths below about 150 g/cm² in a R = 75 cm chondrite.

References


Fig. 1. Calculated production rates of ⁶⁰Co as a function of depth in spherical chondrites. Lines and dashes are the rates calculated here for R = 75, 100, 150, 300, 600, and 1000 g/cm². Triangles, circles, and squares are rates calculated by [1] for R = 40, 75, and 150 cm. The dot-dash line is the lunar curve of [9] normalized to our semi-infinite plane source strength.