COSMOGENIC NUCLIDE PRODUCTION IN SMALL SPHERICAL METEOROIDS. M. S. Spergel, York College of CUNY, Jamaica, NY 11451 and Brookhaven National Laboratory, Upton, NY 11973; R. C. Reedy, Los Alamos Scientific Laboratory, Los Alamos, NM 87545; O. W. Lazareth and P. W. Levy, Brookhaven National Laboratory, Upton, NY 11973

The cosmic-ray induced neutron production in meteoroids creates an equilibrium neutron distribution which, in turn, controls the generation of stable and radioactive nuclides. The formation rates of cosmogenic isotopes at a particular depth are determined by the parent nuclide concentration, the reaction cross sections and the neutron flux energy spectrum. The reaction rates involving nuclides with large energy dependent cross sections will be strongly dependent on the neutron flux spectrum. The distributions of cosmogenic nuclides in planetary and lunar surfaces has been calculated using nuclear reaction production models by various authors (1-6). References (1-3) describe nuclide production in meteoroids using only spallation reactions induced by energetic (E > 1 MeV) particles. Reference (4) describes a slowing-down model used to estimate neutron capture reaction rates in meteoroids. Lingenfelter et al. (5) and Kornblum and Fireman (6) have used multigroup transport techniques to calculate the equilibrium neutron distribution and the induced nuclide distribution in the lunar soil.

Described here is a new calculation that utilizes multigroup neutron transport techniques to obtain the depth and energy dependence for both the equilibrium neutron and cosmogenic isotope distributions in iron and chrondritic spherical meteoroids of various radii. The calculational procedures using the ANISN transport codes were similar to those of (7-9). The equilibrium neutron distribution computation utilizes recently compiled neutron cross section data (8). The neutron distributions, particularly at low energy, will depend on temperature, chemical composition--especially the hydrogen concentration (7), and the radius (9), except for large or very small meteoroids.

The calculation assumes a neutron source produced by cosmic rays, isotropically incident on the spherical meteoroid. The neutron source energy dependence is due to contributions from both evaporation and "knock-on" neutrons (6-8). The relative neutron production and depth dependences were estimated from H^3 production rates calculated for the Moon (10) and for meteorites using GCR flux models like those in (3). The neutron source strengths were normalized to the lunar value of 12.8 n/cm^2s (11). A depth dependence of the neutron source has also been considered from other references (5,6).

The energy dependence of the neutron flux distribution depends critically upon meteorite size and composition. The equilibrium neutron depth distribution and the induced nuclides are almost independent of the source depth distribution. The characteristic "1/E" energy dependence for the distribution, reported by earlier workers (4-8) for large objects, is replaced

by more complex structures for meteorites less than 150 g/cm^2 in radius. This is a consequence of neutrons leaking from the meteorites before they are "thermalized." Consequently, the resulting production rates of cosmogenic nuclei should be calculated only by integrating the neutron flux distribution into the reaction cross section over a broad range of energies. In this way cobalt and nickel production rates have been calculated for spherical meteorites with radii of 10-300 g/cm^2. The shape of the depth dependence of the cobalt production rates is seen to vary with meteorite size in the radius range considered.

References

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1. Arnold J.R., Honda M. and Lal D. (1961) J. Geophys. Res. 66, 3519-3531.
2. Kohman T.P. and Bender M. (1967) in High Energy Nuclear Reactions in Astrophysics, Shen B.S.P., ed., p. 169-245.
3. Reedy R.C., Herzog G.F. and Jessberger E.K. (1979) Earth Planet. Sci. Lett. 44, p. 341-348.
4. Eberhardt P., Geiss J. and Lutz H. (1963) in Earth Science and Meteorites, Geiss J. and Goldberg E.D., ed., p. 143-168.
5. Lingenfelter R.E., Canfield E.H. and Hampel V.E. (1972) Earth Planet. Sci. Lett. 16, p. 355-369.
6. Kornblum J.J. and Fireman E.L. (1974) Center for Astrophysics, Smithsonian Astrophysical Observatory, Preprint Series No. 51.
7. Lapides J.R., Spergel M.S., Lazareth O.W., Levy P.W., Reedy R.C., and Trombka J.I. (1980) Lunar and Planetary Science XI, p. 605-607.
8. Spergel M.S., Lazareth O.W., Slatest L.A. and Levy P.W. (1980) Lunar and Planetary Science XI, p. 1069.
9. Spergel M.S., Reedy R.C., Lazareth O.W. and Levy P.W. December (1980) Meteoritic.
10. Reedy R.C. and Arnold J.R. (1972) J. Geo. Phys. Res. 77, p. 537-555.
11. Woolum D.S., Burnett D.S., Furst M. and Weiss J.R. (1975) The Moon 12, p. 231-250.