**PRODUCTION OF COSMOGENIC NUCLIDES IN THICK TARGETS BY ALPHA BOMBARDMENT.** Rick L. Paul, Peter A.J. Englert[1], Lennox J. Harris[1], Iuda Goldman[2], Charles Jackson[2], RuthMary Larimer[2], Kevin T. Lesko[2], Beth Napier[2], Eric B. Norman[2] and Bhaskar Sur[2]. [1]Nuclear Science Facility, San Jose State University, San Jose, CA 95192. [2]Nuclear Science Division, Lawrence Berkeley Laboratory, Berkeley, CA 94720.

Although decades have passed since the discovery of cosmic rays, determination of the flux of this cosmic radiation in our solar system has remained difficult. Several methods have been employed to study the flux of this radiation. One such method is to monitor cosmic ray flux by determining cosmogenic nuclides (i.e. nuclides formed by interaction of cosmic rays with matter) in meteorites. This procedure suffers from a lack of knowledge of production rates of these nuclides from the major meteoritic target materials. A second way to study the cosmic ray flux involves the use of radiation detection equipment aboard space craft. A major drawback of this technique is that cosmic rays may interact with detector crystals, producing new radionuclides, thus giving rise to large errors in the measured cosmic ray flux.[1]

Although both solar and galactic cosmic particle radiation consist predominantly of high energy protons, galactic cosmic rays contain constant proportions of alpha particles (~12%) and heavier nuclides (~1%), while the alpha particle fluence of the solar cosmic radiation varies. Production of cosmogenic nuclides from SCR alpha particles can thus be simulated by irradiating suitable target materials in alpha particle beams spanning the energy range of SCR particles (~50-200 MeV).[2]

In order to study the production rates of cosmogenic nuclides from SCR alpha particles on planetary surfaces and in remote spacecraft radiation detectors, we prepared thick targets for irradiation from the following materials: C, Mg, Al, Si, $SiO_2$, Fe, and Ni (all highly abundant on planetary surfaces), as well as Ge and $Bi_4Ge_3O_{12}$ (principal components of radiation detector crystals). All thick targets were cylindrical, each target being of sufficient thickness to stop the beam. We also prepared approximately 40 thin Au foils (.001 mm thickness) to be used as flux monitors. All targets were prepared from ultrapure materials.

Irradiations of all targets were performed with the 88 Inch Cyclotron at Lawrence Berkeley Laboratory. Each thick target was irradiated for 10-45 minutes with 60, 90 or 120 MeV alpha particles. To monitor beam intensity, one or two thin Au foils were irradiated with each thick target.

Determination of radionuclides in the targets was carried out by gamma-ray spectroscopy. Measurements were taken using four Ge(Li) detectors (previously calibrated for efficiency with $^{133}$Ba, $^{152}$Eu, $^{56}$Co, $^{60}$Co, and $^{88}$Y sources) in conjunction with the MaestroI multichannel analyzer program. Peak fitting and integration were carried out using GELIFT, a computer program available at LBL.

Alpha particle flux (total incident alpha particles) for each irradiation was calculated using $^{196}$Au activities measured in each of the Au monitor foils and previously determined values for the $^{197}$Au($\alpha$,$\alpha$n)$^{196}$Au cross section for 60, 90 and 120 MeV alpha particles[3]. Production yields for radioactive nuclides produced in the thick targets were then determined. Average cross sections, $\sigma$ (E), for the production of these nuclides over the energy ranges 120-90 MeV and 90-60 MeV were subsequently calculated using the total stopping power of the alpha particles in MeV cm$^2$/atom [4].

Table 1 gives production yields and average cross sections for selected nuclides produced in carbon, aluminum and germanium targets. Production yields and average cross sections for nuclides produced in the Mg, Si, $SiO_2$, Fe and Ni targets (especially those for long-lived cosmogenic nuclides) will be reported at a later date.

REFERENCES: [1] W.A. Mahoney, J.C. Ling and A.S. Jacobson (1984) Astrophys. J., 278, 784. [2] G. Brinkman (1979) PhD. dissertation, Universitat zu Koln.[3] J. Tobailem, C-H. de Lassus St-Genies and L. Leveque (1971). Report CEA-N-1466(1). [4] C. Williamson and J.P. Boujot (1962). Report CEA-2189.

*Table 1*

| Production nuclide | Halflife | $\gamma$ Energy [KeV] | $\gamma$ Intensity [%] | Target element | Production Yields [nuclei/incident $\alpha$ particles] 60MeV | 90MeV | 120MeV | Average Production Cross Section [mb] 120-90MeV | 90-60MeV |
|---|---|---|---|---|---|---|---|---|---|
| $^{7}Be$ | 53.3 d | 477 | 10.4 | C | 1.64E-04 | 5.44E-04 | 8.54E-04 | 15.3 | 24.8 |
| $^{28}Mg$ | 21.1 h | 401 | 35.9 | Al | 1.45E-06 | 3.13E-06 | 4.35E-06 | 0.115 | 0.207 |
| $^{24}Na$ | 15.03 h | 1369 | 100. | Al | 3.68E-05 | 2.73E-04 | 5.12E-04 | 22.5 | 29.1 |
| $^{22}Na$ | 2.62 y | 1274 | 99.9 | Al | 1.77E-04 | 2.82E-04 | 5.86E-04 | 28.7 | 13. |
| $^{7}Be$ | 53.3 d | 477 | 10.4 | Al | 2.52E-06 | 2.45E-05 | 5.23E-05 | 2.62 | 2.71 |
| $^{73}Se$ | 7.1 h | 361 | 96.7 | Ge | 3.12E-04 | 4.67E-04 | 4.71E-04 | 0.797 | 40.3 |
| $^{72}Se$ | 8.4 d | 834 | 92. | Ge | 1.40E-04 | 1.93E-04 | 2.31E-04 | 7.57 | 13.7 |
| $^{76}As$ | 26.3 h | 559 | 44.7 | Ge | 7.79E-05 | 1.15E-04 | 1.28E-04 | 2.59 | 9.62 |
| $^{74}As$ | 17.4 d | 596 | 60.3 | Ge | 2.92E-04 | 6.32E-04 | 7.77E-04 | 28.7 | 88.5 |
| $^{71}As$ | 2.7 d | 175 | 83.6 | Ge | 2.36E-04 | 5.52E-04 | 8.17E-04 | 52.7 | 82. |
| $^{69}Ge$ | 39 h | 574 | 11. | Ge | 1.00E-04 | 4.68E-04 | 8.74E-04 | 80.9 | 95.5 |
| $^{68}Ge$ | 270.8 d | 1077 | 3.3 | Ge | 4.67E-05 | 1.50E-04 | 3.51E-04 | 40. | 26.8 |
| $^{65}Zn$ | 243.8 d | 1115 | 50.7 | Ge | 8.53E-06 | 6.13E-05 | 2.43E-04 | 36.2 | 13.7 |