Subterranean production of neutrons, ^{39}Ar and ^{21}Ne: Rates and uncertainties

WILLIAM F. MCDONOUGH[1*], ONDREJ ŠRÁMEK[2*], L. STEVENS[1], S. MUKHOPADHYAY[3], R. J. PETERSON[4]

[1]Department of Geology, University of Maryland, College Park, MD 20742, USA
[2]Department of Geophysics, Faculty of Mathematics and Physics, Charles University in Prague, Czech Republic
[3]Department of Earth and Planetary Sciences, University of California Davis, Davis, CA 95616, USA
[4]Department of Physics, University of Colorado Boulder, Boulder, CO 80309, United States, USA
(*corresp: mcdonough@umd.edu, ondrej.sramek@gmail.com)

An accurate understanding of the subsurface production of radionuclide ^{39}Ar rate is necessary for argon dating techniques and noble gas geochemistry of the shallow and the deep Earth, and is also of interest to the WIMP dark matter experimental particle physics community. Our new calculations of subsurface production of neutrons, ^{21}Ne, and ^{39}Ar take advantage of the best available tools of nuclear physics to obtain reaction cross sections and spectra (TALYS) and to evaluate neutron propagation in rock (MCNP6). We discuss our method and results in relation to previous studies and show the relative importance of various neutron, ^{21}Ne, and ^{39}Ar nucleogenic production channels. Uncertainty in nuclear reaction cross sections, which is the major contributor to overall calculation uncertainty, is estimated from variability in existing experimental and library data. Depending on selected rock composition, on the order of 10^7–10^{10} particles are produced in one kilogram of rock per year (order of 1–10^3 /kg s), the number of produced neutrons is lower by ~6 orders of magnitude, ^{21}Ne production rate drops by an additional factor of 15–20, and another at least one order of magnitude is dropped in production of ^{39}Ar. Our calculation yields a nucleogenic $^{21}Ne/^4He$ production ratio of (4.6 ± 0:6)×10^{-8} in Continental Crust and (4.2 ± 0.5) ×10^{-8} in Oceanic Crust and Depleted Mantle. Calculated ^{39}Ar production rates span a range from 29 ± 9 atoms/kg-rock×yr in the K–Th–U-enriched Upper Continental Crust to (2.6 ± 0.8) ×10^{-4} atoms/kg-rock×yr in Depleted Upper Mantle.