Reactor Production of Thorium-229

Saed Mirzadeh, Rose A. Boll, Marc Garland, Charles W. Alexander

Oak Ridge National Laboratory

The rapidly increasing interest in the clinical applications of bismuth-213 coupled with the limited availability of thorium-229 necessitate investigation of alternative production routes for Th-229, Ra-225 and Ac-225. Currently, U-233 is the only viable source for high purity Th-229, however, the anticipated growth in demand for Ac-225 may soon exceed the levels of Th-229 present in the aged U-233 stockpile. It is estimated that only ∼38 g or ∼8 Ci of Th-229 can be extracted from entire U-233 stockpile, which is only 80 times the current ORNL 229Th stock. Considering the rather low annual production rate of Th-229 from U-233 (0.92 mCi/kg) and increasing difficulties associated with the U-233 safeguard, routine processing of U-233 is presently unfeasible. The alternative routes for the production of Th-229, Ra-225 and Ac-225 include both reactor and accelerator approaches. Th-229 can be produced from neutron transmutation of Ra-226 and Ra-228 targets [Appl.Radiat.Isot., 49, 345 (1998)]. The theoretical production yields are hampered by the lack of neutron capture cross-section data of the intermediate radionuclides. Using conservative values for the unknown cross sections, the yield of Th-229 is on the order of 0.02 mCi per mg of Ra-226 for a 100-day irradiation at a neutron flux of 2×10^{15} n·s^{-1}·cm^{-2}, with a thermal to epithermal ratio of 20. Note that under these conditions, the amount of Th-228 and Ac-227 contaminants which are co-produced with Th-229 are 4000 and 70 times larger, respectively. Nevertheless, even from a mixture of Th-228 and Th-229, high purity Ac-225 can be obtained from the mixture by initially extracting Ra from Th and then extracting Ac-225 from the Ra mixture (Ra-224, the daughter of Th-228, alpha decays to Rn-220 with no β-decay to Ac-224). Recycling the Ra-226 target will theoretically result in an increase in the yield of Th-229 due to the formation of Ra-228.

The results of two irradiations at the Hydraulic Tube Facility of ORNL High Flux Isotope Reactor (HFIR) will be presented. In these experiments, targets were 33.5 and 330 mg of Ra-226 and were irradiated for one and three reactor cycles (∼24-d cycle) , respectively.

Email: mirzadehs@ornl.gov