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Versatile Monazite: Resolving geological records and solving challenges in materials science

Monazite as a promising long-term radioactive waste matrix: Benefits of high-structural flexibility and chemical durability†

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Abstract

Monazite ($Ln^{3+}PO_4$) and related solid solutions are a well-known source of rare earth elements on earth. They may also accommodate large amounts of thorium and uranium without sustaining damage to the structure by self-irradiation. Such observations led to monazite-type structures being proposed as a potential host matrix for sequestering long-lived radionuclides produced during the nuclear fuel cycle and/or plutonium and americium from dismantled nuclear weapons. Monazite has two main advantages as a matrix for the containment of radioactive waste (or "radwaste"). The first is a highly flexible structure that permits accommodation of high concentrations of actinides. The incorporation of trivalent elements may be achieved by direct synthesis of $An^{3+}PO_4$ (An^{3+} = plutonium, Pu to einsteinium, Es), while tetravalent cation incorporation requires coupled substitutions, either on the anionic site (leading to monazite-huttonite solid solution) or on the cationic site (monazite-cheralite solid solution). Various methods developed for the preparation of such compounds are summarized here, as well as the experimental conditions required for the production of sintered pellets, with a particular focus on plutonium-bearing compositions. The second highly favorable property of monazite is its high chemical durability. Several experimental procedures developed to determine normalized leaching rates are reviewed, as well as results obtained from natural and synthetic monazite. Potential phases formed during dissolution were considered because they also partially control the concentration of actinides in the media. A preliminary list for such phases of interest, as well as corresponding thermodynamic data, is presented.

Keywords: Monazite, actinides, leaching, synthesis, phosphate, radwaste matrix