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Secular disequilibrium in radiopure materials

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Sourcing radiopure materials for use in ultra-low background detectors is critical to the success of rare-event searches (i.e., direct detection of dark matter, neutrinoless double beta decay, etc.). When considering material radiopurity, minimizing contributions from primordial radionuclides (i.e., 238U and 232Th) and their progeny is a matter of the utmost importance. Current inductively coupled plasma mass spectrometry assay capabilities can measure 232Th and 238U down to the nanoBq/kg level. In comparison, radiometric counting methods are typically several orders of magnitude less sensitive, even for decay chain progeny for which they are most sensitive. When direct determination of the entire decay series is not possible, due to insufficient sensitivity, many experiments assume secular equilibrium within a decay series. However, physical and chemical processes in material manufacturing can significantly fractionate the decay series, resulting in secular disequilibrium. This may lead to inaccurate background predictions and mischaracterized detector sensitivities, ultimately hampering detector performance and reducing the likelihood of successful detection.

In this work we report results from a comprehensive literature review to evaluate the current understanding of secular equilibrium in materials used for ultra-low background detectors. We use this framework to discuss current and future research geared towards understanding the processes that perturb secular equilibrium during materials production. Finally, we provide examples of how this information can be leveraged to develop/improve ultra-radiopure materials for future generation experiments.

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