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Development of an Ultrasensitive ICP-MS Assay Method for the Determination of Uranium, Thorium and Potassium in Gadolinium Used in Scintillator Materials

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The development of ultra-low background gadolinium-loaded liquid scintillator (Gd-LS) is critical for current and next-generation experiments in neutrino and rare-event physics, including supernova neutrino detection, reactor monitoring, and as a neutron veto in dark matter searches. The presence of trace radioactive contaminants such as ^{238}U , ^{232}Th , and ^{40}K can introduce backgrounds that severely limit sensitivity. In this work, we present a novel, highly sensitive inductively coupled plasma mass spectrometry (ICP-MS) assay method capable of quantifying ^{238}U , ^{235}U , ^{232}Th , and ^{40}K at microBq/kg levels in complex gadolinium compounds used in scintillator production. The developed method incorporates an ultra-clean dry ashing and separation procedure that minimizes contaminant introduction during sample processing as well as spectral interferences and matrix effects during mass spectrometric analysis. The method has been successfully applied to the organic-based $\text{Gd}(\text{TMHA})_3$ material used in the LUX-ZEPLIN (LZ) experiment's Gd-LS neutron veto, enabling a better understanding of the background contributions and ultimate sensitivity reach of the detector. This method provides a foundation for quality assurance in future low-background experiments utilizing Gd-LS and offers a high-throughput approach capable of processing batches of scintillator precursor compounds within days at sensitivities not achievable using other techniques.

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