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Modeling Impurity Concentrations in Liquid Argon Detectors

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Impurities in noble liquid detectors used for neutrino and dark matter experiments can significantly impact the quality of data. We present an experimentally verified model for describing the dynamics of impurity distributions in liquid argon (LAr) detectors. The model considers sources, sinks, and transport of impurities within and between the gas and liquid argon phases. Measurements of the oxygen concentration in a 20-L LAr multi-purpose test stand are compared to calculations made with this model to show that an accurate description of the concentration under various operational conditions can be obtained. A result of this analysis is a determination of Henry's coefficient for oxygen in LAr. These calculations also show that some processes have small effects on the impurity dynamics and excluding them yields a solution as a sum of two exponential terms. This solution provides a simple way to extract Henry's coefficient with negligible approximation error. The simplified model is applied to the data and the extracted Henry's coefficient for oxygen in LAr is consistent with published results. Based on the analysis of the data with the model, we further suggest that, for a large liquid argon detector, barriers to flow ("baffles") installed in the gas phase with large coverage can help reduce the ultimate impurity concentration in the LAr. A 260L LAr system is presently being commissioned for further studies of the model and also for future performance and optimization studies of LArTPCs.

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