

Depletion Calculation of Subcritical System with Consideration of Spontaneous Fission Reaction

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We enabled to consider the spontaneous fission reaction in subcritical neutron multiplying system by modifying the OpenMC depletion calculation code version 0.11. The code ability was successfully shown to provide information on short half-life fission products over time and the relationship between the activity ratio of ⁸⁸Kr-to-¹³⁵Xe and effective neutron multiplication factor.

Keywords: subcritical system; burnup calculation; subcriticality; spontaneous fission product; Monte Carlo calculation;

1. Introduction

In the current work, we modify the OpenMC [1] transport and depletion code version 0.11 and enable the modified code to perform depletion calculation for the subcritical nuclear multiplying system with consideration of spontaneous fission reaction as inherent external sources.

2. Calculation Method and Results

The Bateman equation for the depletion calculation can be written as $\frac{dN(t)}{dt} = M(R, S) \cdot N(t)$, with transmutation matrix $M(R, S) = R \cdot S + D$. The OpenMC depletion chain is the basis for decay matrix (D), and it contains a collection of neutron interaction, neutron-induced fission, and decay modes from ENDF/B-VII.1 [2] but without spontaneous fission information. Therefore, we modified the OpenMC code to include the spontaneous fission products (FPs) into the decay matrix (D) by using the spontaneous fission product yields sub-libraries of TENDL-2011 [3]. The induced FPs contribution was calculated based on the effective neutron multiplication factor (k_{eff}), reaction rate (R), and normalization factor (S) which are obtained from transport calculation. We performed a preliminary calculation of the fuel debris canister filled with nuclear material and spontaneous fission nuclide (²⁴⁴Cm). Consequently, we have successfully obtained the information on the number of short half-life nuclides $N(t)$ such as ⁸⁸Kr and ¹³⁵Xe (Figs. 1 and 2) and the relationship between the activity ratio of ⁸⁸Kr-to-¹³⁵Xe and k_{eff} (Fig. 3).

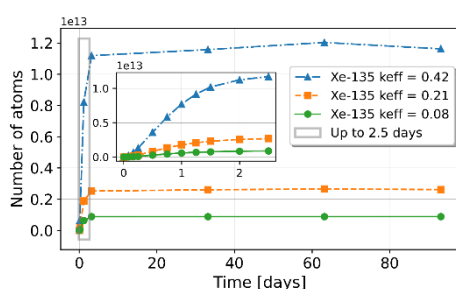


Fig. 1 Number of ¹³⁵Xe versus time (days) for different k_{eff}

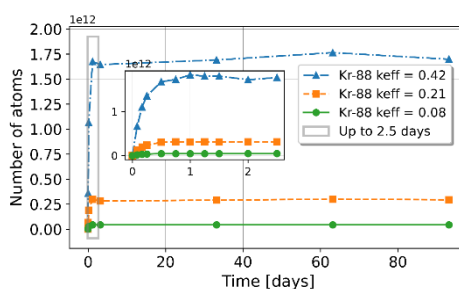


Fig. 2 Number of ⁸⁸Kr versus time (days) for different k_{eff}

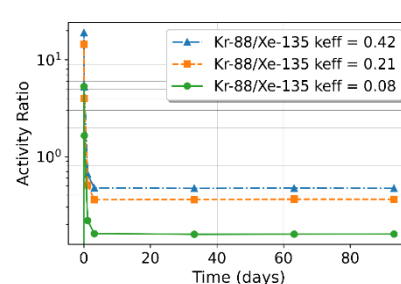


Fig. 3. Activity ratio of ⁸⁸Kr/¹³⁵Xe versus time (days)

3. Conclusion

Modification of the OpenMC depletion calculation code to consider spontaneous fissions in a subcritical system has been successfully performed. The calculation result shows the ability of the modified code to provide information on the quantity of short half-life FPs over time and to provide the relationship between the activity ratio of ⁸⁸Kr-to-¹³⁵Xe and canister effective multiplication factor (k_{eff}).

References: [1] Paul K. Romano, et al., Ann. Nucl. Energy. 2015; 82: 90–97. [2] Available from: <https://openmc.org/depletion-chains/> [cited 2020 Nov 9]. [3] Koning A.J and Rochman D. Nuclear Data Sheets. 2012; 113: 2841-2934.