A classification of CEMP stars based on neutron density that reveals the important role of the i process and the need for better nuclear physics data

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Most C-enhanced metal poor stars show simultaneously substantial enhancements of heavy n-capture elements, such as Sr, Y, Zr, Ba, La and Eu. These have been commonly classified according to the presence of the element Ba which is dominantly made by the s-process and of Eu which has an s-process production contribution of only $\sim 3\%$, and is therefore considered an r-process element. We are revisiting the classification of CEMP stars with the goal to establish more granular criteria based on the neutron-density prevailing in the stellar nuclear production site. To this end we have constructed equilibrium nucleosynthesis simulations for $6 < \log N_{\mathrm{n}} < 23$. These models are independent of any specific astrophysical site. After demonstrating how well these constant N_{n} simulations represent more realistic astrophysics-based nucleosynthesis simulations we compare the simulations with the JINAbase databased of CEMP stars. Most stars labeled CEMP-s in that data base cannot be reproduced by s-process neutron density models, but instead by the intermediate neutron density, demonstrating the importance of the i process for understanding the heavy-element patterns in CEMP stars. Our analysis involves elemental ratios of both first and second peak, and reveals that predictions of observational abundance ratios are severely limited by nuclear physics uncertainties, especially the (n, γ) rate of n-rich unstable species 2 - 6 masses off the valley of stability. This new type of analysis lends itself to a systematic nuclear physics impact study approach, and we will present results from three such studies that have revealed a handful of (n, γ) reactions that should be measured with the highest priority. We will briefly summarize the present state of simulations in 3D and 1D of the most likely astrophysical sites of the i process.