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Informing Neutron Capture Nucleosynthesis on Short-Lived Nuclei with (d,p) Reactions

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Neutron capture reactions are responsible for the synthesis in stars of essentially all of the elements heavier than iron through either the \textit{s} or \textit{r} process. While the \textit{s} process proceeds near stable nuclei, the \textit{r}-process waiting points are short-lived and far from stability. Recent studies [1] have demonstrated that unknown (n,γ) rates on nuclei near the \textit{r}-process path, and in particular near closed neutron shells, could have significant impact on predicting abundances with \textit{r}-process network calculations. Constraining (n,γ) rates could also serve to inform our knowledge of the site of the \textit{r} process. Of particular interest are the $N<82$ tin isotopes.

Neutron capture near closed shells can proceed by two processes. Direct (including semi-direct) capture can be deduced if the spectroscopic factors of low-spin states have been measured, for example, with (d,p) reactions with radioactive ^{126,128,130}Sn beams[2] For open neutron shell nuclei, neutron capture is expected to predominately proceed through the population of a compound nucleus with gamma decay that proceeds by many paths. While the population of the compound nucleus can be calculated with optical models, the decay depends upon the level density and γ-ray strength function, whose properties cannot be accurately extrapolated to weakly bound nuclei, far from stability.

We have recently validated the (d,pγ) reaction as a surrogate for (n,γ) with stable ^{95}Mo targets [3]. The measured (d,p) cross sections and γ-ray decay probabilities as a function of excitation energy and angular momentum were interpreted in a Hauser-Feshbach approach [4]. The ^{96}Mo compound nucleus was assumed to be populated by neutrons following the inelastic breakup of the deuteron [5] and the transferred angular momentum in the (d,p) reaction deduced from the measured cross sections. We are able to reproduce the measured and evaluated ^{95}Mo(n,γ) cross sections [6]. The (d,p) reaction is particularly well suited for studies with radioactive ion beams because the reaction protons are preferentially observed at back angles in the laboratory and can be measured in a position sensitive array of silicon strip detectors, such as ORRUBA and coupled to a gamma-ray detector array [7].

This presentation would summarize the validation of the (d,p) reaction as a surrogate for (n,γ) and discuss opportunities for (d,pγ) studies on nuclei near the \textit{r}-process path at radioactive beam facilities in the U.S. and Italy.

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\noindent[1] M. Mumpower \textit{et al.}, Prog. Nucl. Part. Phys. \textbf{86}, 86 (2016); \\
\noindent[2] R. L. Kozub \textit{et al.}, Phys. Rev. Lett. \textbf{109}, 172501 (2012) and B. Manning to be published; \\
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}

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