Modelling of Astrophysics Processes *

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We have previously outlined a set of requirements for determining when a nuclear reaction cross section should be measured [1]. These are: 1) an appropriate model for an astrophysical process significant for nucleosynthesis, 2) an observable from that process, 3) demonstrated dependency of the observable on the particular reaction cross section, and 4) an experimental strategy for measuring that cross section, or at least using measurable data to better calculate it. Experimental nuclear physicists have the largest role in satisfying requirement 4), but astrophysicists play the leading role in evaluating the other three criteria.

In our previous work, we identified the alpha-rich freezeout in core-collapse supernovae as a significant astrophysical process and ^{44}Ti as an important resulting observable. We then followed a strategy of systematically varying reaction cross sections and groups of reaction cross sections to identify those reactions that govern the nucleosynthesis of ^{44}Ti. In the present work, we identify ^{56}Co (produced as parent ^{56}Ni) and ^{57}Co (produced as parent ^{57}Ni) as other significant observables from the alpha-rich freezeout. Following our previously developed strategy, we have surveyed the cross section sensitivities of the nucleosynthesis of ^{56}Ni and ^{57}Ni.

The alpha-rich-freezeout yield of ^{56}Ni is extremely robust against factor of ten changes in any strong or electromagnetic nuclear reaction cross section. This is expected since this nucleus is largely produced in equilibrium. ^{57}Ni is also extremely robust against changes in all reaction cross sections except for the reaction ^{57}Ni(n,p)^{57}Co. This reaction governs when ^{57}Ni breaks out of quasi-equilibrium. The magnitude of the effect is such that a factor of three increase (decrease) in the reaction cross section from the standard value [2] leads to a $\sim$10% decrease (increase) in the ^{57}Ni yield. The yield of ^{57}Ni in a core-collapse supernova, as determined by observation of gamma rays from the decay of daughter ^{57}Co, gives important constraints on supernova models [3]. An accurate measurement of ^{57}Ni(n,p)^{57}Co (or the reverse reaction ^{57}Co(p,n)^{57}Ni) would improve the predictions of the models, thereby leading to better constraints on them.

We have surveyed the reaction cross section sensitivities of yields of other isotopes of iron and nickel from alpha-rich freezeouts. The results of these surveys may be view at the Clemson Nuclear Astrophysics web page (http://photon.phys.clemson.edu/tables.html). At present, these other isotopes tie into no direct astrophysical observable. Presolar meteoritic grains may provide the best opportunity. In any case, it is clear that both the nuclear physics and astrophysics communities benefit when modelling of astrophysical processes is accompanied by identification of possible astrophysical observables from those processes and demonstration of reaction cross section sensitivities of those observables.

[1] L.-S. The *et al.*, Astrophys. J. **504**, 500 (1998).
[2] Thielemann, F.-K. *et al.*, in Advances in Nuclear Astrophysics, ed. E. Vangioni-Flam *et al.* (Gif-sur-Yvette: Éditions Frontières), 525.
[3] J. Kurfess *et al.*, Astrophys. J. Lett. **399**, L137 (1992).

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