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Capture Cross Sections for Unstable Isotopes from Surrogate Reaction Data and Theory

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Obtaining reliable data for nuclear reactions on unstable isotopes remains an extremely important task and a formidable challenge. Neutron capture cross sections – crucial ingredients for models of astrophysical processes, national security applications and simulations of nuclear energy generation – are particularly elusive, as both projectile and target in the reaction are unstable. Various methods have been proposed for determining capture cross sections from indirect measurements. The 'surrogate reaction method' [1] uses inelastic scattering or transfer ('surrogate') reactions to produce the compound nucleus of interest and measure its subsequent decay. In principle, this data provides constraints for the models describing the decay of the compound nucleus, which dominate the uncertainties of the cross section calculations. Past applications of the surrogate approach assumed the decay to be independent of the mechanism that formed the compound nucleus. This approximation, which neglects the need to describe the surrogate reaction, works reasonably well for (n,f) cross sections [2], but has long been known to break down for capture reactions [3].

This contribution demonstrates that a proper theoretical description of the surrogate reaction mechanisms is key to overcoming the limitations encountered previously. Specifically, theoretical descriptions of the (p,d) and (d,p) transfer reaction have been developed to complement recent measurements in the Zr-Y-Mo region. The procedure for obtaining constraints for unknown capture cross sections is illustrated and indirectly extracted cross sections for both known (benchmark) and unknown capture reactions are presented. The method makes no use of auxiliary constraining quantities, such as neutron resonance data, or average radiative widths, which are not available for short-lived isotopes; thus it can be applied to isotopes away from stability.

[1] Escher et al, RMP 84, 353 (2012).
[2] Escher and Dietrich, PRC 74, 054601 (2006).
[3] Forssen et al, PRC 75, 055807 (2007); Escher and Dietrich, PRC 81, 024612 (2010); Scielzo et al, PRC 81, 034608 (2010); Chiba and O. Iwamoto, PRC 81, 044604 (2010); Boutoux et al, PLB 712, 319 (2012); Ducasse et al, PRC 94, 024614 (2016).

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