Coulomb dissociation reactions on Mo isotopes for astrophysics applications

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Introduction

Photo-dissociation reactions play an important role in p-process nucleosynthesis, which takes place in supernova explosions. Theoretical calculations of isotopic abundances of the p-nuclei require a vast reaction network linking thousands of isotopes, where most of the reaction rates must be derived from the Hauser-Feshbach statistical model. However, as many rates as possible need to be determined experimentally, in order to provide a reliable reference for the calculations.

Measuring reaction rates on Mo isotopes is important to explain the problem of the significant underproduction of ^{92}Mo and ^{96}Ru in all existing models of p-process nucleosynthesis. Another aspect of the project is to verify the accuracy of the Coulomb dissociation method by comparing our data with experiments performed with real photons at S-DALINAC (TU Darmstadt) and ELBE (FZD) [1].

Experiment and preliminary results

At the FRS/LAND setup at GSI, Coulomb dissociation experiments on the stable ^{92,94,100}Mo and unstable ^{93}Mo isotopes were performed in order to extract (γ,n) and (γ,2n) reaction cross sections. The used method is ideal to investigate unstable isotopes, since the reaction is studied in inverse kinematics: a beam containing nuclei of interest impinges on a high-Z target (Pb). Under certain conditions, such as a sufficiently high energy and a large impact parameter, a reaction takes place between the projectile and a virtual photon originating from the Coulomb field of the target nucleus.

In order to extract the electromagnetic excitation cross sections from the measurement with the Pb target, background reactions must be taken into account. A measurement with a carbon target was performed to estimate the contribution of nuclear reactions at the target, whereas a measurement without any target was done to determine the background from all kinds of reactions outside the target.

Our setup provides the possibility to detect all reaction products, thus delivering kinematically complete data. The incoming and outgoing nuclei are identified with respect to A and Z on an event-by-event basis. Evaporated neutrons with all their characteristics are measured by the LAND detector [2]. Combining this information allows a clean selection of the reaction channel.

Preliminary integral Coulomb-excitation cross sections for three reaction channels are presented in Table 1. Statistical uncertainties of the data are less than 3%, but a non-negligible systematic uncertainty is present and is estimated at around 10%.

Although the setup should provide the possibility to reconstruct the excitation energy spectrum *via* the invariant mass method, difficulties were encountered on the way to understand the efficiency of the CsI γ-detector, which appeared to be unexpectedly low. The overall response of the setup is very complex and does not allow a deconvolution. We are investigating these issues.

Integrated Coulomb-excitation cross sections for ^{100}Mo were compared to the measurement by Beil *et al.* [3] after convoluting the latter with the E1 component of the virtual photon spectrum (see Table 1). Beil *et al.* used a monoenergetic photon beam produced by positron annihilation to measure the following total photoabsorption cross sections: $\sigma_\gamma(\gamma,n) = \sigma[(\gamma,n)+(\gamma,pn)]$ and $\sigma_\gamma(\gamma,2n) = \sigma[(\gamma,2n)+(\gamma,pnn)]$. In our data, the proton removal channels are clearly separated and are not analyzed. However, in the case of ^{100}Mo, the proton removal threshold is high enough to neglect the contribution of this channel. In the case of ^{92}Mo(γ,n), a direct comparison was not possible due to the low (γ,np) reaction threshold.

It should be noted that the photoabsorption data [3] might need to be scaled additionally by a factor 0.85, as suggested by Berman *et al.* [4]. The authors assume that the discrepancy might come from a wrong estimation of the photon flux and/or neutron detection efficiency by Beil *et al.* [3].

The data analysis is in progress. As a next step, the Coulomb-excitation cross section for ^{93}Mo will be calculated. It is of particular interest, since this isotope is unstable and its cross section has never been measured before.

Reaction	σ_{CE}(prelim.), mb	σ_{CE}([3]), mb
^{100}Mo(γ,n)^{99}Mo	812	876 ± 30
^{100}Mo(γ,2n)^{98}Mo	285	293 ± 20
^{92}Mo(γ,n)^{91}Mo	437	

Table 1: Integrated Coulomb excitation cross sections for three reaction channels

References

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