Photodisintegration Studies on p-Nuclei: The Case of Sm Isotopes

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In explosive stellar environments like supernovae, the temperatures are high enough for the production of heavy neutron deficient nuclei, the so-called p-nuclei. These are thought to be produced in such scenarios either through chains of photodisintegration reactions like (γ,n), (γ,p) and (γ,α) on heavy seed nuclei or by a recently suggested mechanism interpreted as the νp process[1]. The precise knowledge of the cross sections of these reactions are of crucial importance for the prediction of the p-nuclei abundances in nucleosynthesis network calculations.

At the ELBE bremsstrahlung facility, photodisintegration studies on the astrophysically relevant p-nuclei ^{92}Mo and ^{144}Sm have been performed via the photoactivation technique. All the three types of photodisintegration reactions were observed for the two nuclei and in particular the (γ,α) reactions of the mentioned nuclei were studied for the first time. Bremsstrahlung endpoint energies chosen ranged from 10.0 to 16.5 MeV. Details and main results of the photoactivation studies on ^{92}Mo are comprised in [2].

Samples of fine Sm_2O_3 powder (mass ≈ 3 g, diameter 18 mm) were irradiated in the photoactivation site located behind the electron beam dump together with an Au sample. During the same experiment, another Au sample was irradiated at the target position in the bremsstrahlung cave together with a ^{11}B sample. By using the known ^{197}Au(γ,n) cross section and the known scattering cross section of transitions in ^{11}B we could estimate the photon flux in the electron beam dump. For more details of the experimental setup and method see, [2, 3].

The number of radioactive nuclei $N_{act}(E_0)$ produced in a photoactivation measurement is proportional to the integral of the absolute photon flux $\phi_\gamma(E, E_0)$ multiplied by the photodisintegration cross section $\sigma_{\gamma,x}(E)$ from the reaction threshold energy E_{thr} up to the bremsstrahlung spectrum end-point energy E_0:

$$N_{act}(E_0) = N_{tar} \cdot \int_{E_{thr}}^{E_0} \sigma_{\gamma,x}(E)\phi_\gamma(E, E_0)dE.$$

The symbol x stands for the emitted particle (i.e, n,p or α). N_{tar} is the number of target atoms in the sample. $N_{act}(E_0)$ can be experimentally determined with a low-level counting setup using the HPGe detector as

$$N_{act}(E_0) = N_\gamma(E_0, E_\gamma) \cdot \kappa_{corr}/(\epsilon(E_\gamma) \cdot p(E_\gamma)).$$

Here $N_\gamma(E_0, E_\gamma)$ denotes the full-energy peak counts of the observed transition corrected for dead-time and pile-up , $\epsilon(E_\gamma)$ and $p(E_\gamma)$ stand for the absolute full-energy peak efficiency of the detector and the emission probability of the photon for the energy E_γ, respectively. The factor κ_{corr} accounts for the decay losses during irradiation and measurement and this corrects the measured number of decays to the number of radioactive nuclei in the sample.

Measured reaction yields relative to the ^{197}Au reaction yield are as shown in fig. 1. The experimental data are compared with the yield integrals calculated with a simulated thick-target bremsstrahlung spectrum and photodisintegration cross sections predicted by Hauser-Feshbach models [4, 5]. The ^{144}Sm(γ,n) reaction cross section is dominant for energies above 10.5 MeV. Since ^{144}Sm(γ,p) has the reaction threshold at 6.3 MeV, it is necessary to do the experiment with endpoint energies between 6.3 MeV and 10.5 MeV in order to measure pure (γ,p) yields. Experiments in this regard are in progress.

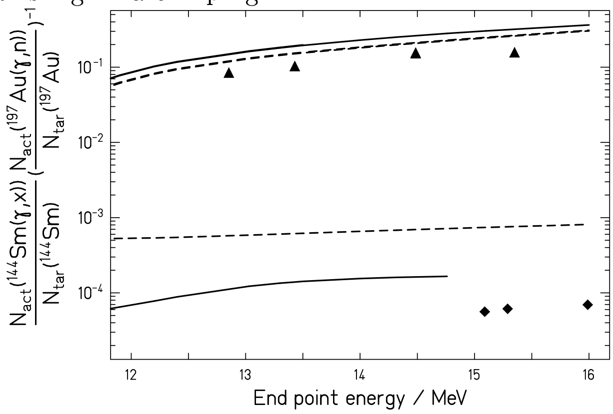

Fig. 1 *Experimental activation yields for photodisntegration reactions on ^{144}Sm isotopes normalized to the activation yield from ^{197}Au(γ,n) irradiated simultaneously. Symbols stand for ^{144}Sm(γ,n) (triangles) and ^{144}Sm(γ,α) (diamonds). The solid line shows calculations using cross sections from [4] and the dotted one stands for the predictions from [5]*

[1] C. Fröhlich et al., Phys. Rev. Lett. 96 (2006) 142502
[2] M. Erhard et al., PoS-(NIC-IX) 056 (2006)
[3] R. Schwengner et al., NIM A 555 (2005) 211
[4] T. Rauscher, F. -K. Thielemann, Atomic Data and Nuclear Data Tables 88 1(2004)
[5] A. J. Koning et al., AIP-(ND-2004) 769 (2005) 1154

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