Chapter 80
First Radiative Proton-Capture Cross-Section Measurements in Mid-Weight Nuclei Relevant to the *p*-Process

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Abstract One of the important, but still unsettled topics in Nuclear Astrophysics is the production of the p-nuclei. The p-process relies on an extended reaction network, which can be described theoretically by the Hauser–Feshbach statistical model, which in turn relies strongly on experimental data. To provide reliable data for p-nuclei, an experimental campaign at the Tandem Accelerator Laboratory of NCSR "Demokritos", focusing on ^{107,109}Ag$(p,\gamma)^{108,110}$Cd and ^{112}Cd $(p,\gamma)^{113}$In reaction cross-sections measurements was carried out. Both reactions were studied using a set of four HPGe detectors via the in-beam γ-ray spectroscopy, while for the latter the activation method was additionally employed to account for the population of a low-lying isomeric state. Total cross sections for proton beam energies lying inside the Gamow window for energies relevant to p-process nucleosynthesis were obtained for the first time. Experimental results are compared to Hauser–Feshbach calculations performed with the latest version of the TALYS code (v1.9). An overall good agreement has been achieved. These results provide important new input for the theoretical description of the p-process, but additionally for the origin of the cross-point p-nucleus ^{113}In.

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80.1 Introduction

Explaining the solar abundances of the *p*-nuclei remains an open question for nuclear astrophysics. Their production site is not well settled yet, but the most promising scenario for the *p*-process to-date is the photodisintergation of s- and r-seed nuclei in the O/Ne layer of core-collapse supernovae.

As far as it concerns nucleosynthesis, the *p*-process reaction network involves thousands of nuclei, and rates are estimated in the framework of the Hauser–Feshbach statistical model. Its efficiency relies strongly on experimental input of proton-, alpha- and neutron-induced reaction cross sections, which can adjust parameters and thus improve the theoretical predictions for unmeasured reactions rates [1, 2]. To that end, a campaign of measurements at the Tandem Accelerator Laboratory of NCSR "Demokritos" focusing on radiative proton capture measurements on ^{107,109}Ag [3] and ^{112}Cd [4] in the energy range of *p*-process nucleosynthesis was undertaken.

80.2 Experimental Details

Both reactions involve *p*-nuclei never studied before. In this work, radiative proton-capture reactions were studied by means of in-beam γ-ray spectroscopy. For the case of ^{112}Cd$(p,\gamma)^{113}$In the activation method was additionally used to account for a low-lying isomeric state in ^{113}In (E = 391.7 keV, $t_{1/2}$ = 99.5 min).

The detection apparatus comprised four 100% HPGe detectors, mounted on a turntable (Fig. 80.1), so as to obtain angular distributions of the transitions of interest. In the case of ^{107,109}Ag$(p,\gamma)^{108,110}$Cd reaction, no significant angular dependence was observed in contrast with ^{112}Cd$(p,\gamma)^{113}$In (see Fig. 80.3). For each reaction the total cross section was deduced by measuring photopeak intensities of all the transitions feeding the ground state of the produced nucleus.

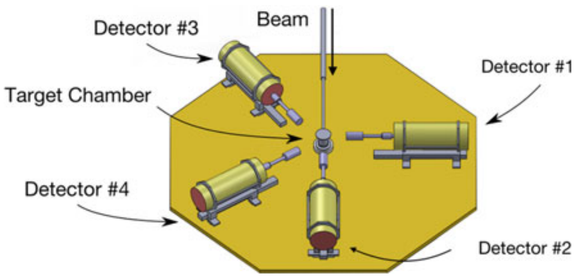

Fig. 80.1 A sketch of the experimental setup

80.3 Results and Conclusion

Measured cross sections for the ^{107}Ag$(p, \gamma)^{108}$Cd reaction are shown in Fig. 80.2, while preliminary results for the ^{112}Cd$(p, \gamma)^{113}$In are shown in Fig. 80.3. The experimental results are compared to Hauser–Feshbach calculations employing the latest version of the TALYS code (v1.9) [5]. A total of 96 different model combinations of the three main ingredients of the TALYS code, i.e. the Optical Model Potential (OMP), the Nuclear Level Density (NLD), and the γ-ray Strength Function (γSF) (See Table 80.1), resulted in the shaded areas shown.

It is worth mentioning that compared to [3], the experimental points are the same, however the Hauser–Feshbach calculations have been performed with the newest version of TALYS (v1.9) and a finer energy step ($\approx$8 keV). In addition, the effect of the γSF was exclusively studied by keeping the OMP and NLD unchanged. The combination of OMP and NLD used (See Table 80.1) seems to well reproduce the experimental data both in trend and magnitude.

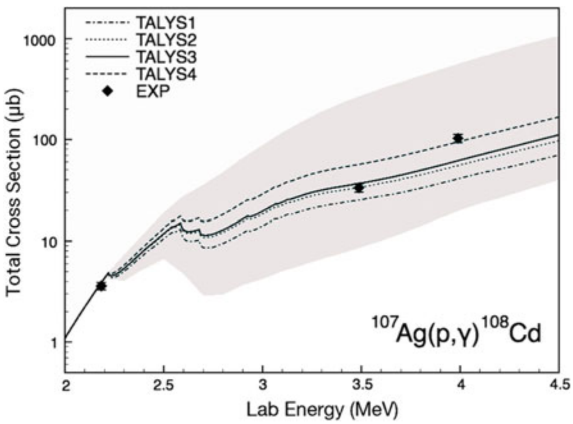

Fig. 80.2 ^{107}Ag(p, γ) reaction cross sections

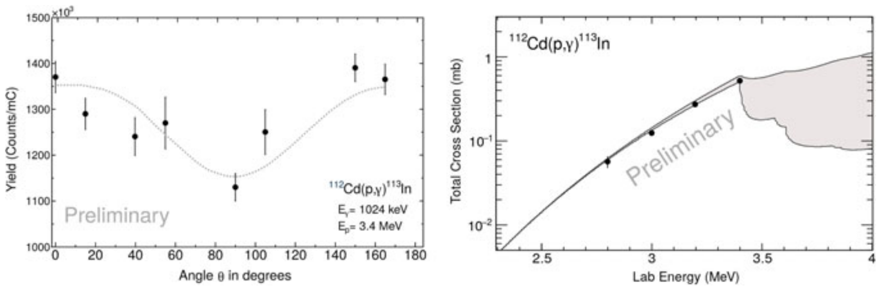

Fig. 80.3 (Left) A typical γ angular distribution (1024 keV, $E_p = 3.4$ MeV) (Right) Total reaction cross sections for the ^{112}Cd$(p, \gamma)^{113}$In reaction

Table 80.1 Combinations of models used in TALYS for the ^{107}Ag$(p, \gamma)^{108}$Cd reaction

Model	OMP	NLD	γSF
TALYS1	BDG[a]	THBFBG[b]	Kopecky-Uhl
TALYS2	BDG	THBFBG	HFB tables
TALYS3	BDG	THBFBG	HFB-BCS tables
TALYS4	BDG	THBFBG	Gogny D1M
			HFB + QRPA

[a]BDG Bauge-Delaroche-Girod
[b]THFBG T-dependent HFB, Gogny force

Note that for the ^{112}Cd$(p, \gamma)^{113}$In reaction, at E $=$ 3.4 MeV, the respective (p, n) channel threshold is reached, hence the wide spread of model predictions thereafter (shaded region in the left panel of Fig. 80.3).

The reported (partially preliminary) results show an overall good agreement with the theoretical predictions of the TALYS code. The present study provides valuable new input for the theoretical modeling of the p-process, but undoubtedly, more experimental studies in the mass region are needed to shed light on the complex nucleosynthesis network in this mass regime.

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