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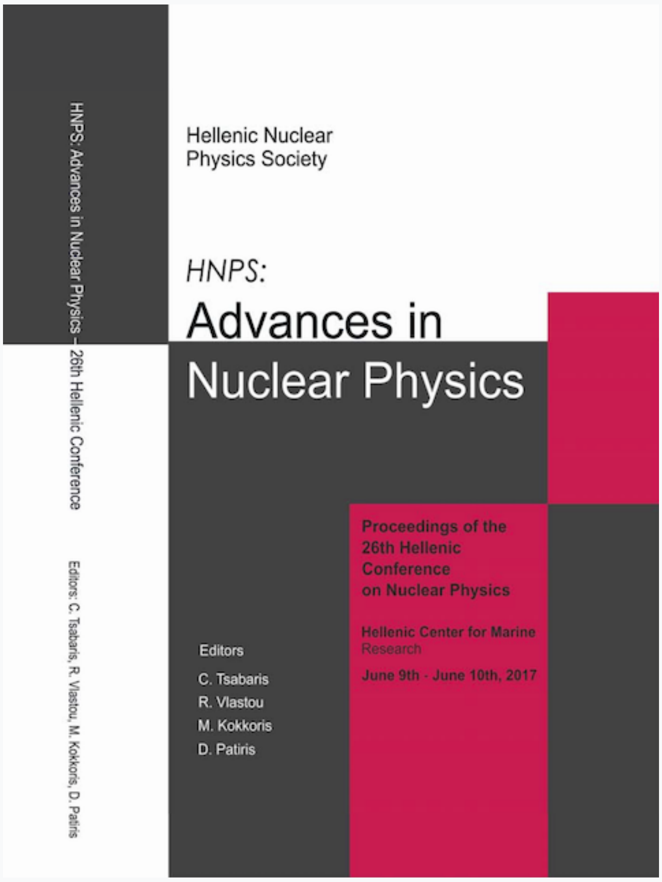

A systematic study of (t,p) reactions in mid-heavy nuclei using TALYS

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A systematic study of (t,p) reactions in mid-heavy nuclei using TALYS

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Abstract Tritium-capture, proton-radiative reactions, more commonly known as (t,p) reactions, can provide important input for both nuclear structure and nuclear astrophysics studies. Experimental data for (t,p) reactions exist for very small atomic masses. However, such data are scarce for medium and heavy nuclei. In the present work, several nuclei between mass 120 and 140 are considered in a systematic theoretical investigation of (t,p) reactions using the TALYS v1.8 code and a variety of nuclear input parameters. The detailed study has focused to the total cross sections and results have been compared with the TENDL-2015 library. In addition, the inverse reaction (p,t) was studied for selected isotopes to trace down similarities and differences in the dynamics involved for both channels. The results are expected to augment our understanding of such processes in the particular mass region and provide guidance for future experimental endeavors.

Keywords detector efficiency, curve-fitting algorithms

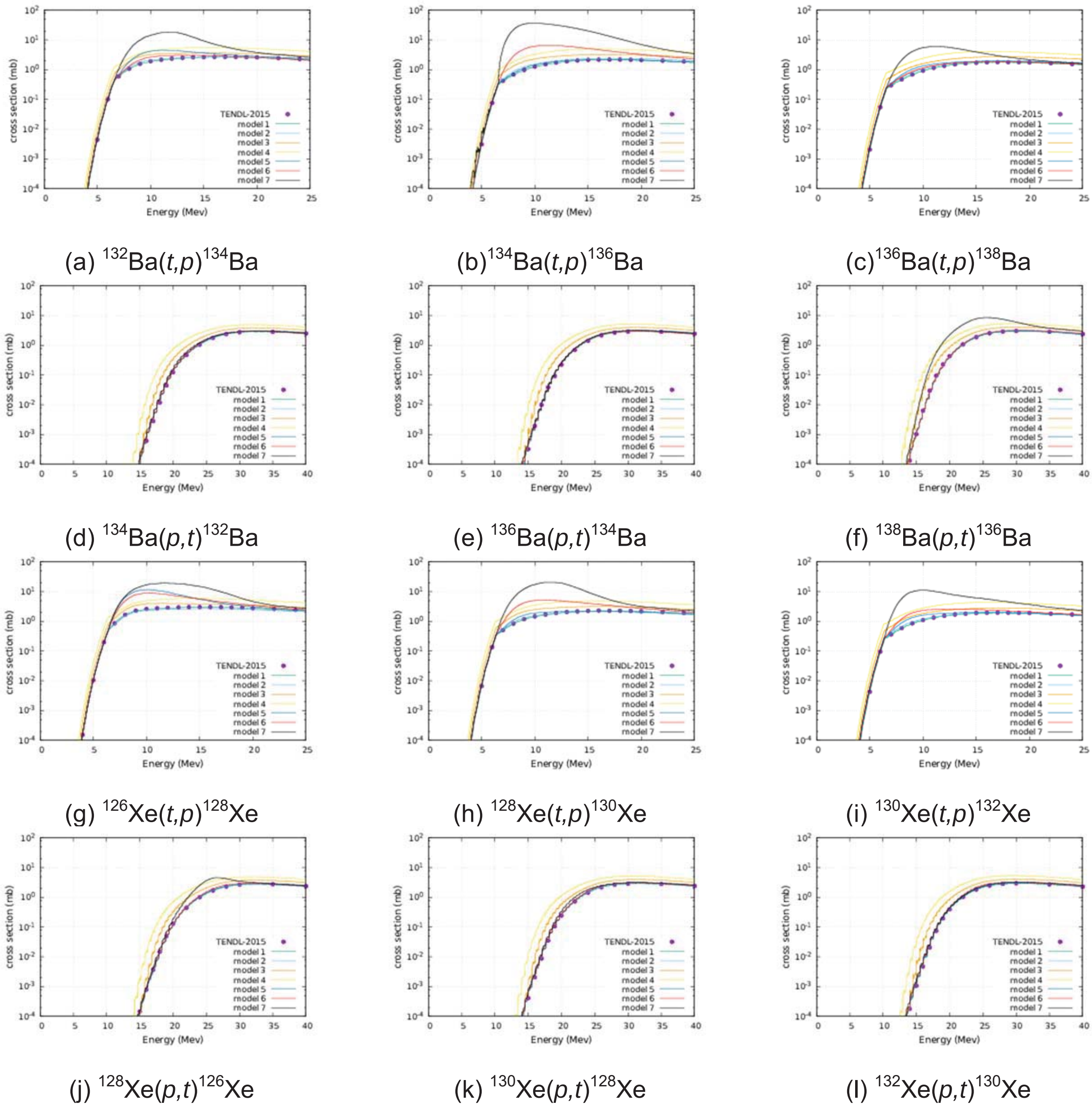
INTRODUCTION

Tritium (^{3}H) beams can be used to probe various nuclear systems and provide information on nuclear structure and reaction characteristics. Such beams are not as common as the lighter protons or deuterons, a fact strongly reflected in the amount of available information in evaluated nuclear databases [1]. Tritium is an excellent probe for populating neutron-rich isotopes, especially in (t,p) reactions, which add two extra neutrons to the target nucleus. Such reactions are particularly useful for structure studies in nuclei residing along the s-process path.

The scarcity of experimental cross section data for (t,p) reactions with mid-heavy nuclei motivated the present work. A systematic study was undertaken using the TALYS [2] code in an attempt to calculate total cross sections of (t,p) reactions with several stable nuclei around A~130. Among others, the results of these calculations for Ba and Xe isotopes are reported in this article. In addition, the inverse (p,t) reactions are also studied in an attempt to understand the dynamics of the reactions in terms of the optical model potential (OMP), the nuclear level densities (NLD) and the γ-ray strength functions (γSF).

METHODOLOGY

TALYS v1.8 code was used to carry out calculations in medium-weight nuclei with an atomic number between 106 and 138, for stable isotopes of Cd, Ar, Pd, Sn, I, Cs, Xe and Ba elements, using the default choices for OMP, NLD and γSF. In total, 7 different models have been studied (see Table 1 for description of combinations) and results are given for stable Ba and Xe isotopes only, as this research work is still ongoing. All calculations have been performed with an energy step of 7 keV. No Coulomb barrier corrections have been applied in the results shown in Fig. 1.



(a) ^{132}Ba(*t*,*p*)^{134}Ba (b) ^{134}Ba(*t*,*p*)^{136}Ba (c) ^{136}Ba(*t*,*p*)^{138}Ba

(d) ^{134}Ba(*p*,*t*)^{132}Ba (e) ^{136}Ba(*p*,*t*)^{134}Ba (f) ^{138}Ba(*p*,*t*)^{136}Ba

(g) ^{126}Xe(*t*,*p*)^{128}Xe (h) ^{128}Xe(*t*,*p*)^{130}Xe (i) ^{130}Xe(*t*,*p*)^{132}Xe

(j) ^{128}Xe(*p*,*t*)^{126}Xe (k) ^{130}Xe(*p*,*t*)^{128}Xe (l) ^{132}Xe(*p*,*t*)^{130}Xe

Fig. 1. Total cross sections calculated for (t,p) and (p,t) reactions on Ba and Xe isotopes

	Optical Model Potential	*Nuclear Level Density*	*γ Strength Function*
Model 1	Koning-Delaroche [3]	CTM [4]	Brink-Axel [5]
Model 2	JLM [6]	CTM	Kopecky-Uhl [7]
Model 3	Koning-Delaroche	BFM [8]	Kopecky-Uhl
Model 4	Koning-Delaroche	GSM [9]	Kopecky-Uhl
Model 5	Koning-Delaroche	Skyrme force Goriely [10]	Kopecky-Uhl
Model 6	Koning-Delaroche	Skyrme force Hilaire [11]	Kopecky-Uhl
Model 7	Koning-Delaroche	HFB [12]	Kopecky-Uhl

Table 1. Initial settings for the optical model potential, the nuclear level densities and the γ strength function used in TALYS v1.8 for all calculations reported in this article.

RESULTS AND CONCLUSIONS

Results from the calculations are illustrated in a graphical format in Fig. 1, panels (a)-(l). The results for each particular isotope have been compared with the TENDL-2015 library (solid points). For each model in Table 1 the effect of the direct, the compound and the pre-equlibrium channel on the total cross section has been calculated. (t,p) reactions of Ba and Xe isotopes are shown in Figs. 1(a)-(c) and 1(g)-(i), respectively. Cross sections of the inverse (p,t) reactions are depicted in Figs. 1(d)-(f) and 1(j)-(l), respectively.

Overall good agreement between the TENDL-2015 library data and some of the models has been achieved, as it is evident in Fig. 1. At low energies, the optical model potential (Koning-Delaroche in all but one models) has the dominant effect on the total cross sections. In higher energies, the effects of NLD and γSF become more prominent. Despite not corrected for Coulomb barrier that is expected to correct for the threshold energy, the cross section dependence on the energy shows distinct differences between the (t,p) and (p,t) reactions involving the same initial and final nucleus. It is reasonable to mention that more thorough investigation is required to understand these differences in terms of the nuclear model parameters (OMP etc). In that direction, more work is under progress.

From the above rather gross features of the calculated cross sections with TALYS a strong point emerges: more experimental data are necessary to understand the dynamics ruling those reactions, especially in mid-heavy nuclei that attract quite a lot of attention both for nuclear structure and nuclear astrophysics investigations (critical symmetries, s-process etc).

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