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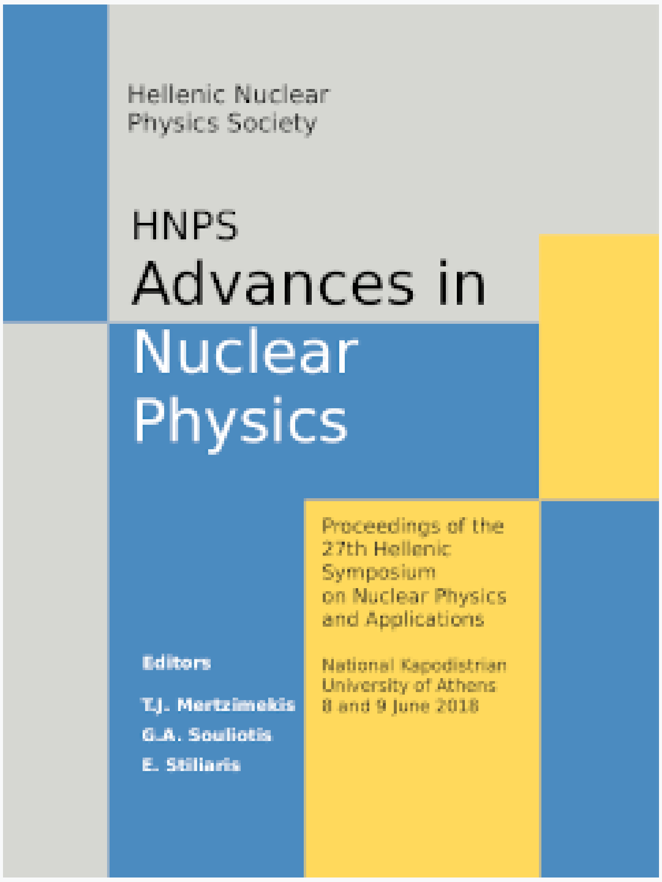

Statistical-model calculations for α-capture reactions relevant to the p process

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Statistical-model calculations for α-capture reactions relevant to the *p* process

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Abstract About 35 nuclides which lie on the neutron deficient side of the isotopic chart cannot be created by the two basic nucleosynthetic processes, the *s* and the *r* process. Due to scarce experimental data and the vast complexity of the reaction network involved, cross sections and reactions are estimated theoretically, using the Hauser–Feshbach statistical model. In the present work, theoretical calculations of cross sections of radiative α-capture reactions on the neutron–deficient Erbium and Xenon isotopes are presented in an attempt to make predictions inside the astrophysically relevant energy window (Gamow). The particular reactions are predicted to be sensitive branchings in the *γ* process path.

The most recent versions of TALYS (v1.9) and Fresco codes were employed for all calculations, initially focusing on investigating the influence of the default eight (8) α–nucleus optical potential models of TALYS on reaction cross sections. The theoretical results of both codes are compared and for the reactions where experimental data exist in literature, the optical model parameters were adjusted appropriately to best describe the data and were subsequently used for estimating (*α*,*γ*) reaction cross sections. Predictions for the (*α*,*n*) reaction channels have also been calculated and studied.

Keywords p–process, p–nucleus, cross section, TALYS, FRESCO

INTRODUCTION

The *p* process is responsible for about 35 neutron–deficient nuclides, called the *p* nuclei. The dominant theory suggest that the *p* process takes place in the O/Ne shell of a Type II core-collapse supernova, by subsequent (γ,n), (γ,p) and (γ,α) reactions, as well as β^+ decays and electron-captures. Because of the dominant role of photodisintegrations, this process is also called "*γ* process". Experimental data for the cross sections of these reactions in the Gamow window are scarce, and predictions rely mostly on theoretical calculations, which involve a huge reaction network of about 20,000 reactions. In this work, cross section calculations of the a-capture reactions on the neutron–deficient Erbium and Xenon isotopes using different *α*–nucleus optical potential models are reported. These isotopes are located in sensitive branchings in the *γ* process path [1], and their detailed study is very important both experimentally and theoretically.

METHODOLOGY

In order to calculate the theoretical predictions, two codes were employed, TALYS (v.1.9) [2] and Fresco (v.3.2) [3]. Specifically TALYS was used to study the influence of the eight (8) *α*–nucleus optical potential models (*alphaomp*) and the six (6) level densities models (*ldmodel*) on the reaction cross sections. Afterwards, the optical model parameters, such as *awadjust*, which can finetune one of the optical potential parameters (Table 1), were altered appropriately to best describe the data and were subsequently used for estimating

(α,γ) reaction cross sections. In addition, simultaneous predictions for the (α,n) reaction channels were calculated and studied.

Parameter		*alphaomp*	*ldmodel*	*awadjust*
Default		Normal alpha potential	Constant T + Fermi gas model	1
Adjustment	**Xe**	Avrigeanu et al. [6]	Constant T+ Fermi gas model	1.45
	Er	Avrigeanu et al [6]		-

Table 1: Optical model parameters used in TALYS code for Xe and Er isotopes.

RESULTS AND DISCUSSION

For the cases where experimental data exist in the literature [4,5], TALYS was compared to Fresco (Figs. 8 & 9). Both TALYS and FRESCO seem to have the predictive power to model reactions inside the Gamow window, an important energy range for astrophysical systems. There is more work needed to understand the occasional failure of models to describe the data near the (α,n) channel threshold. Theoretical cross sections were calculated for the cases of ^{126,128}Xe(α,γ) reactions, where no experimental data are available in the literature (Fig. 10).

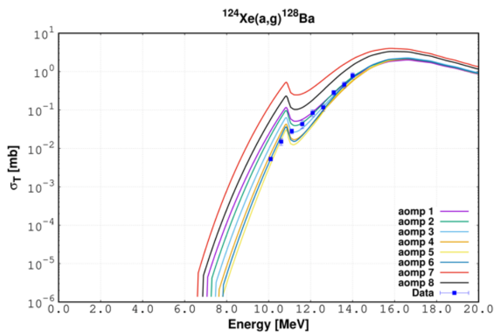

Figure 1: ^{124}Xe(α,γ)^{128}Ba Alpha OMP

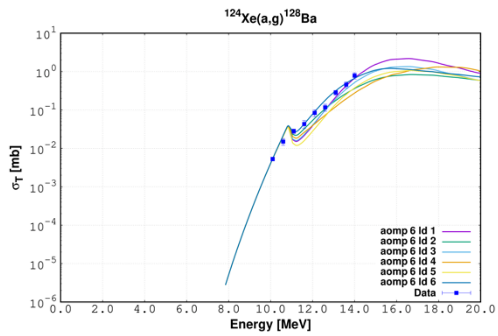

Figure 2: ^{124}Xe(α,γ)^{128}Ba *ldmodel* for *aomp*=6

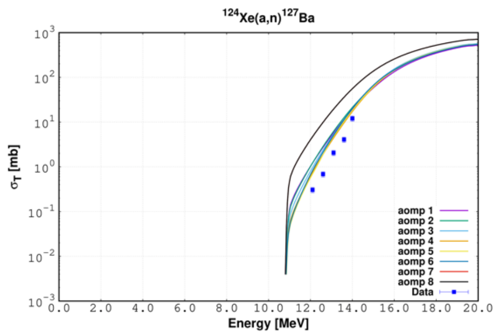

Figure 3: ^{124}Xe(α,n)^{127}Ba Alpha OMP

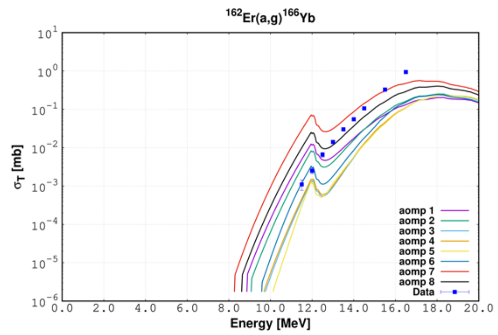

Figure 4: ^{162}Er(α,γ)^{166}Yb Alpha OMP

CONCLUSIONS

In the present study, a detailed sensitivity analysis of the three major parameters involved in statistical modeling of α–capture reactions was presented. By altering the optical model parameters, a better fit of the data to theoretical curves was achieved by those adjustments, which can be used to predict the (α,n) reaction channels. The present findings can be proven useful for both fundamental studies and industrial applications (e.g. nuclear energy etc.). Further investigation is necessary to improve the sensitivity analysis and extend the range of applicability to neighboring isotopes.

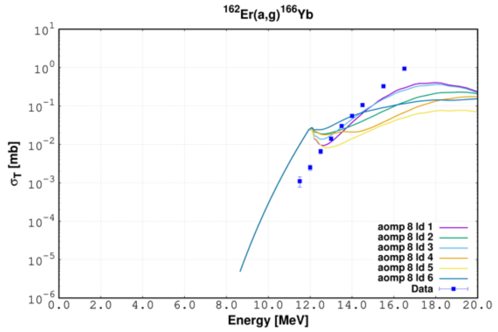

Figure 5: ^{162}Er(α,γ)^{166}Yb *ldmodel* for *aomp*=8

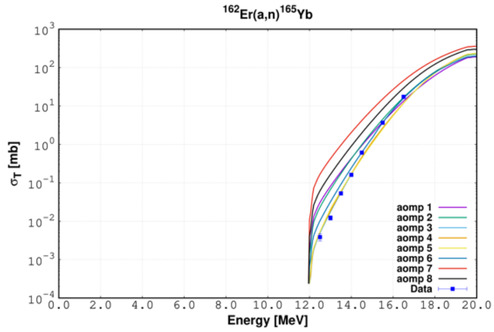

Figure 6: ^{162}Er(α,n)^{165}Yb Alpha OMP

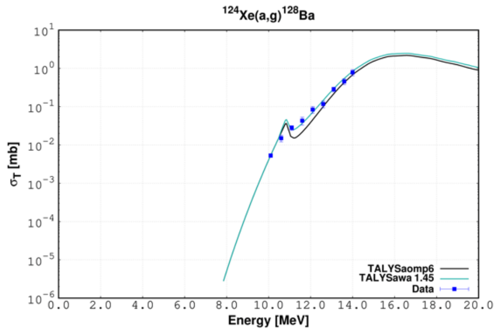

Figure 7: ^{124}Xe(α,γ)^{128}Ba *awadjust* parameter

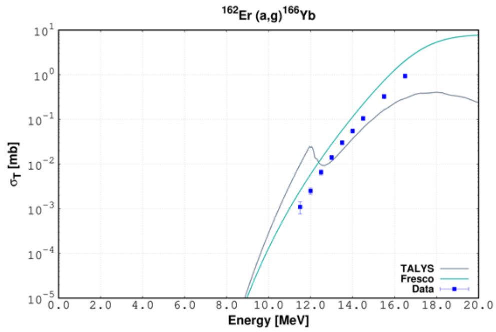

Figure 8: ^{162}Er(α,γ)^{166}Yb Fresco vs TALYS

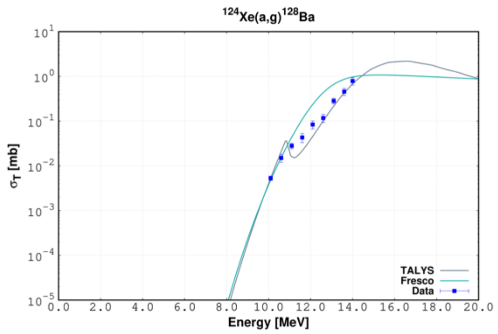

Figure 9: ^{124}Xe(α,γ)^{128}Ba Fresco vs TALYS

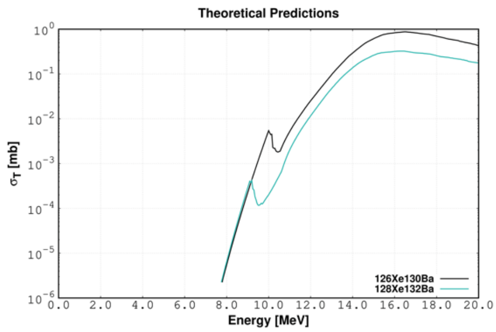

Figure 10: Theoretical predictions ^{126}Xe(α,γ)^{130}Ba & ^{128}Xe(α,γ)^{132}Ba

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