EPJ Web of Conferences **128**, 01004 (2016) DOI: 10.1051/epjconf/201612801004
TESNAT 2016

Theoretical investigation of cross sections and astrophysical S-factors for the $^{92}Mo(\alpha,n)^{95}Ru$ and $^{94}Mo(\alpha,n)^{97}Ru$ reactions

Abdullah Aydin[1], *Ercan* Yıldız[1], *Ismail Hakki* Sarpün[2]

[1]Kırıkkale University, Physics Department, Kırıkkale, Turkey
[2]Afyon Kocatepe University, Physics Department, Afyonkarahisar, Turkey

Abstract. Molybdenum is commonly applied as a constructive material in different types of nuclear reactors. The cross sections of the $^{92}Mo(\alpha,n)^{95}Ru$ and $^{94}Mo(\alpha,n)^{97}Ru$ reactions have been calculated at 5-20 MeV energy ranges. In theoretical calculations, the TALYS1.6 and NON-SMOKER codes were used. Also the astrophysical S-factors were calculated. Results of our calculations were checked to the experimental data obtained from EXFOR database.

1 Introduction

Molybdenum is significant structural material in fusion reactor technologies and astrophysical applications [1]. Therefore, knowledge of the reaction cross sections and astrophysical S-factors on the Mo isotopes are needed. Cross section measurements for charged-particle capture reactions on nuclei heavier than Fe are important for nucleosynthesis studies [2] and for testing statistical model predictions. Although the descent of the abundances of the elements is generally good understood, significant uncertainties still exist [3]. Therefore, recently (α,n) and (α,γ) reaction cross-sections in low energies are measured by several authors [4-9]. The importance of alpha capture cross sections for different mass regions to test the theoretical models is well known [10]. Experimental measurements of cross section, $\sigma(E)$ at very low energies are mainly not available. The rates can be calculated by extrapolation of the astrophysical S-factor to very low energies or determination of the cross section using theoretical models. The information to be obtained about cross sections or astrophysical S-factors in nuclear astrophysics reactions are the main source of information about the nuclear processes in astrophysics. Various studies using theoretical models have been done to predict the alpha capture cross sections at low energies [3,11].

In this study, we calculated the cross sections and the astrophysical S-factors for $^{92}Mo(\alpha,n)^{95}Ru$ and $^{94}Mo(\alpha,n)^{97}Ru$ reactions up to 20 MeV incident energy. In these theoretical calculations, we used TALYS 1.6 [12] and NON-SMOKER [13] codes. Results of our calculations were checked to the experimental data obtained from EXFOR [14] database.

2 Materials and methods

The charged particle nuclear reaction cross sections is given as

$$\sigma(E)=E^{-1}\exp(-2\pi\eta)S(E) \tag{1}$$

where E is the center-of-mass energy of the reactants, S(E) is astrophysical factor and $\eta = (Z_1Z_2e^2)/\hbar\nu$ is the Sommerfeld parameter [15]. Experimental cross section measurements are mainly not available because of the Coulomb barrier. Since the astrophysical S-factor describes the possibility of reaction in low energies, in astrophysical applications, it should be well known for many reactions at low energies ($E \leq$ a few MeV). Also, the astrophysical S-factor is a function of energy with slow variation than $\exp(-2\pi\eta)$ and $\sigma(E)$ [15]. Thus if theoretical astrophysical S-factors are known at low energies, cross sections can be predicted in these energies.

3 Calculations and results

In this study, the reaction cross-sections and the astrophysical S-factors of the $^{92}Mo(\alpha,n)^{95}Ru$ and $^{94}Mo(\alpha,n)^{97}Ru$ reactions were calculated by TALYS 1.6 code and Eq. 2, respectively. The radiative alpha capture reaction cross-sections were calculated in the incident energy range of 5 to 20 MeV, respectively. In these calculations, the TALYS 1.6 and NON-SMOKER codes were used. Also for these reactions, we calculated the astrophysical S-factors which describe the possibility of reaction in low energies. Obtained results were compared to the available experimental data of EXFOR database in Figs. 1–4. It can be seen that there is agreement between the experimental data and calculated results. In $^{92}Mo(\alpha,n)$ and $^{94}Mo(\alpha,n)$ reactions, ^{95}Ru and ^{97}Ru isotopes are produced, respectively. ^{95}Ru isotope ($T_{1/2} = 1.64$ h) decays to ^{95}Tc ($T_{1/2}$ = 20.0 h) and ^{97}Ru isotope ($T_{1/2}$ = 2.83 days) decays to ^{97m}Tc ($T_{1/2}$ = 91.0 days).

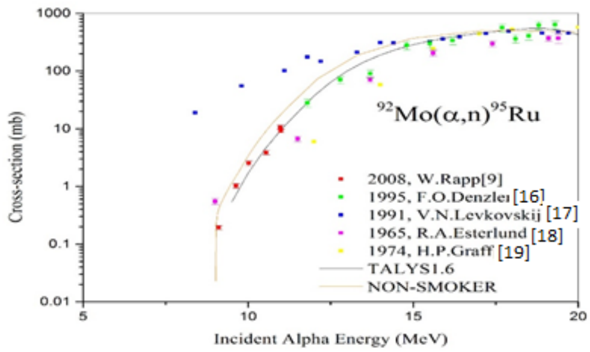

Fig. 1. Comparison of experimental cross sections and theoretical cross sections for ^{92}Mo(α,n) reaction

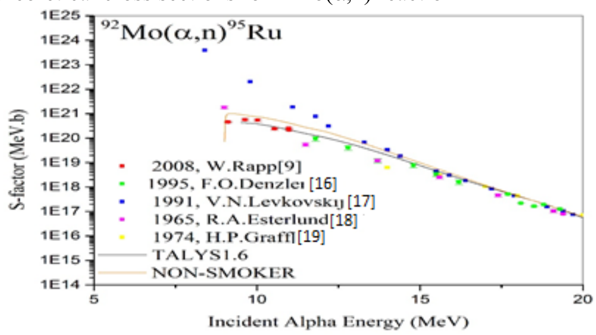

Fig. 2. Comparison of experimental S-factors and theoretical S-factors for ^{92}Mo(α,n) reaction

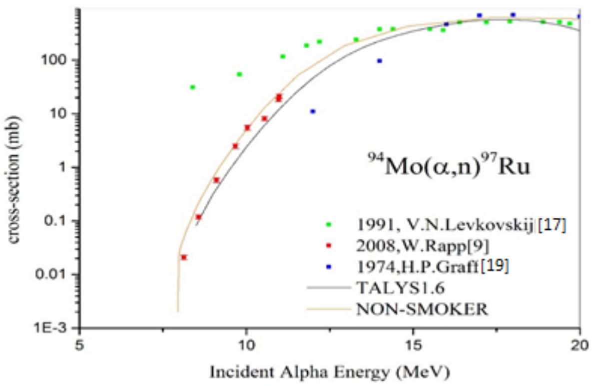

Fig. 3. Comparison of experimental cross sections and theoretical cross sections for ^{94}Mo(α,n) reaction

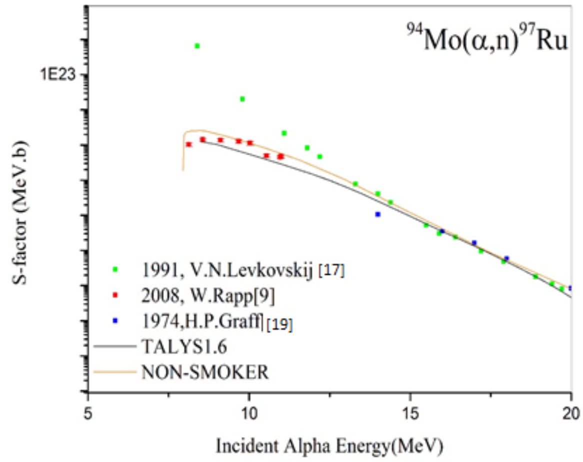

Fig. 4. Comparison of experimental S-factors and theoretical S-factors for ^{94}Mo(α,n) reaction

4 Conclusion

The cross-sections and astrophysical S-factors of the ^{92}Mo(α,n)^{95}Ru and ^{94}Mo(α,n)^{97}Ru reactions have been analyzed at 5-20 MeV. It appears that the agreement between the experimental and evaluated data is reasonable good at the higher energy but poor at the lower energy for these reactions. Therefore, theoretical calculations could be repeated with the new nuclear parameters to obtain the best fit with the experimental data. Also more low-energy experiments are clearly needed for alpha capture reactions in the mass range of nuclei above iron.

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