Afyon Kocatepe Üniversitesi Uluslararası Mühendislik Teknolojileri ve Uygulamalı Bilimler Dergisi

Afyon Kocatepe University International Journal of Engineering Technology and Applied Sciences

AKÜ IJETAS Cilt **4(2)** (2021) Aralık (74-77 s) AKU J.Eng.App.Sci. **Vol 4(2)** (2021) December (74-77pp)

DOI:10.53448/akuumubd.984708

Araştırma Makalesi / Research Article

e-ISSN 2667-4165 (https://dergipark.org.tr/akuumubd

^{112}Sn(α, γ) ^{116}Te Reaksiyonu için Astrofiziksel S-Faktörlerinin ve Reaksiyon Hızlarının Hesaplanması

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The arrival date: 19.08.2021 ; Date of Acceptance: 26.10.2021

Anahtar Kelimeler
Reaksiyon hızı;TALYS; astrofiizksel S-faktör;EXFOR;NON-SMOKER

Öz

Çalışmamızda ^{112}Sn(α, γ)^{116}Te reaksiyonunun reaksiyon hızları hesaplanmıştır. Hesaplamalar için TALYS 1.95 kodları kullanılmıştır. Ek olarak, düşük enerjili bölgelerde bir reaksiyon olasılığını açıklayan astrofiziksel S faktörleri elde edildi. Hesaplamalarımızın sonuçları, EXFOR veri tabanından alınan deneysel verilere göre kontrol edildi.

Calculation of Astrophysical S-factors and reaction rates for reaction ^{112}Sn(α, γ) ^{116}Te

Keywords
Reaction rates; TALYS;astrophysical S-factors;EXFOR;NON-SMOKER

Abstract

In our study, the reaction rates of ^{112}Sn(α, γ)^{116}Te reaction were calculated. TALYS 1.95 codes were used for calculations. In addition, astrophysical S-factors were obtained that explain the probability of a reaction in low-energy regions. The results of our calculations were checked according to experimental data from the EXFOR database.

1. Introduction

Photonuclear reactions play an important role in many different subfields of nuclear astrophysics, and particularly for nucleosynthesis applications. The solar abundance of most of the nuclei heavier than iron is explained by the slow and rapid neutron capture processes known as the s and r processes, respectively (Utsonomiya et al. 2006).

By calculating the reaction rate and astrophysical S-factor of the ^{112}Sn(α, γ)^{116}Te reaction, it is possible to estimate the reaction cross-sections for low energy zones.

2. Material ve Metod

Cross-section values, which are of great importance for understanding a reaction, may not be obtained, especially in the low energy zones. Using the Astrophysical S-factor for these regions will be useful for understanding the reaction.

The astrophysical S-factor is defined as

$$S(E)=\sigma(E).E.exp(2\pi\eta) \qquad (1)$$

where, η is the Sommerfeld parameter, $(Z_1Z_2e^2)/\hbar v$. The astrophysical S-factor is especially helpful in low energy regions. Empirical measurements of σ (E) are often not available in measuring these energies (Yildiz and Aydin 2006). The astrophysical S-factor has been investigated theoretically and practically by different authors and contributed to the literature (Yakovlev et al. 2010, Dubovichenko 2012, Dohet-Eraly et al. 2016, Goncharov 2018, Bysritsky et al. 2013, Ozdogan et al. 2019).

Thermonuclear reaction formula can be expressed in eq. (1)

$$N_A(\sigma\upsilon)_T = N_A[8/\pi m(kT)^3]^{1/2} \int_0^E \sigma(E)E\exp(-E/kT)\, dE \quad (2)$$

where N_A is Avagadro's number, m is reduced mass and E is centre-of-mass energy, and T indicates temperature of the environment for the reaction (Santos et al. 2000).

Experimental studies required for nuclear reactions are not always possible in terms of both material and possibilities. It is not always possible to obtain and use reactants. In such cases, it is advantageous to make theoretical experiments or to make half-experimental calculations with various simulation programs.

For cases where experimental studies cannot be carried out, it is thought that theoretical studies such as we do will contribute.

EXFOR

EXFOR data library is a comprehensive collection of experimental nuclear reaction data, stored and reused.

TALYS (Nuclear Reaction Code)

The TALYS 1.95 (Koning et al. 2017) nuclear code program determines all reaction mechanisms, reaction channels and all observable possibilities using nuclear models. In the simulation reactions created in this program, it can operate in the energy region of 1 keV –1 GeV with n, p, d, t, 3He, α particles and γ beams as bullet particles

NON-SMOKER

NON-SMOKER (Rauscher and Thielemann 2000) is a computer code using the Hauser-Fesbach Model that theoretically calculates cross section values.

3. Results

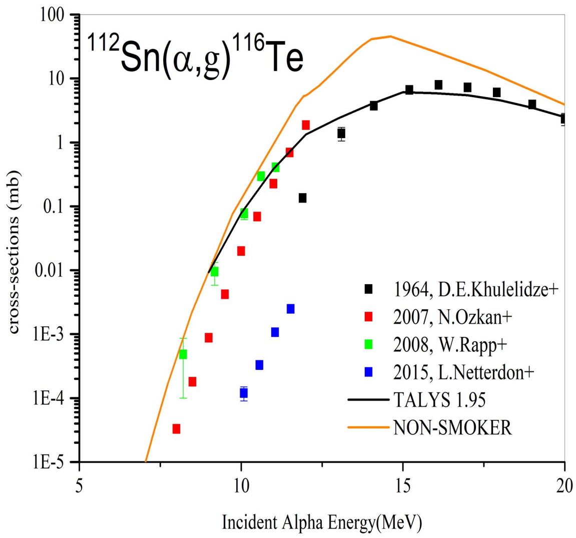

Figure 1. Cross-section values of the $^{112}Sn\ (\alpha, \gamma)^{116}Te$ reaction

Fig. 1, calculated cross-section values of the $^{112}Sn(\alpha, \gamma)^{116}Te$ reaction are shown together with available experimental data. As it can be seen from Fig. 1, experimental cross section values are compatible with the those of Ref.(Khulelidze et al. 1965),(Ozkan et al. 2007) and , (Rapp et al. 2008) ,(Netterdon et al. 2015) values in the range of 10-12.5 MeV. The values of Ref. (Khulelidze et al. 1965) and TALYS 1.95 are almost the same in the range of 13-20 MeV. TALYS 1.95 and NON-SMOKER values are in great similarity in low energy region (9-12 MeV). NON-SMOKER data has a peak around 15 MeV incident alpha energy.

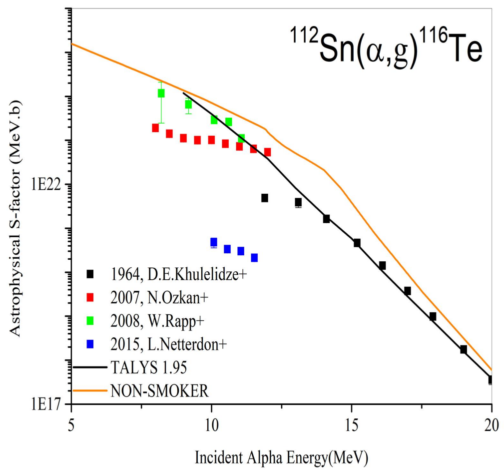

Figure 2. Astrophysical S-factor values of the ^{112}Sn(α, γ)^{116}Te reaction according to alpha energy

If the astrophysical S-factor values are examined in Figure 2, it gives concordant results. Especially in the 13-19 MeV range, (Khulelidze et al. 1965) and TALYS 1.95 values are in remarkable harmony. There is a similar fit in NON-SMOKER. However, similar harmony is not seen in (Netterdon et al. 2015). Using the astrophysical S-factor, the cross-section in the low energy region can be calculated by various fit processes.

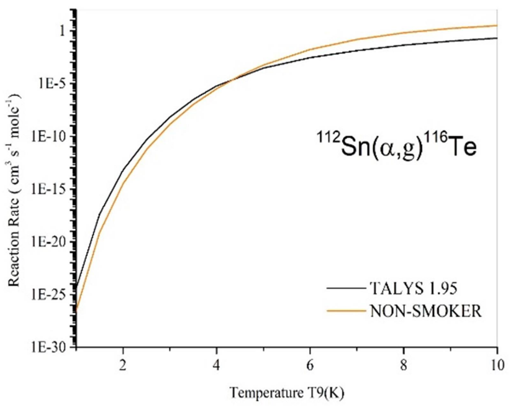

Figure 3. Thermonuclear reaction rates for ^{112}Sn(α, γ)^{116}Te reaction

The thermonuclear reaction rate curves show the expected behaviour as a function of temperature and mass. TALYS 1.95 reaction rates and NON-SMOKER values are compatible.

4. Discussion and Conclusion

It is thought that using such code programs will be very useful in understanding nuclear reactions. It is assumed that it will contribute to the development of programs such as TALYS 1.95 with the increase of experimental studies.

It is thought that the reaction rate calculations will contribute to various estimation and extrapolation studies, especially because it depends on the cross section values. Reaction rate values treated for a reaction allow us to interpret and evaluate the influence cross-section and astrophysical S-factors and Gamow Window. In addition in the low energy region where experimental data is difficult to obtain, it should be stated that experimental studies should be carried out.

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