BIBLIOGRAPHIC INFORMATION SYSTEM

Journal Full Title: Journal of Biomedical Research & Environmental Sciences

Journal NLM Abbreviation: J Biomed Res Environ Sci

Journal Website Link: https://www.jelsciences.com

Journal ISSN: 2766-2276

Category: Multidisciplinary

Subject Areas: Medicine Group, Biology Group, General, Environmental Sciences

Topics Summation: 128

Issue Regularity: Monthly

Review Process type: Double Blind

Time to Publication: 7-14 Days

Indexing catalog: Visit here

Publication fee catalog: Visit here

DOI: 10.37871 (CrossRef)

Plagiarism detection software: iThenticate

Managing entity: USA

Language: English

Research work collecting capability: Worldwide

Organized by: SciRes Literature LLC

Manuscript should be submitted in Word Document (.doc or .docx) through **Online Submission** form or can be mailed to support@jelsciences.com

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Journal of Biomedical Research & Environmental Sciences main aim is to enhance the importance of science and technology to the scientific community and also to provide an equal opportunity to seek and share ideas to all our researchers and scientists without any barriers to develop their career and helping in their development of discovering the world.

JOURNAL OF BIOMEDICAL RESEARCH &ENVIRONMENTAL SCIENCES
issn: 2766-2276
SUBJECT AREA(S): NUCLEAR MEDICINE | RADIATION THERAPY
DOI: 10.37871

RESEARCH ARTICLE

Obtaining Astrophysical S-Factors and Half-Experimental Cross-Section Values for ^{121}Sb (α, n) ^{124}I Reaction

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ABSTRACT

In this study, ^{121}Sb (α, n) ^{124}I reaction, which is one of the production reactions of the ^{124}I radioisotope, which has an important use in nuclear medicine, was investigated. Experimental value EXFOR was obtained and theoretical data was obtained using TALYS 1.8 and NON-SMOKER half-experimental cross section values were calculated using theoretical data and experimental values. In addition, the Astrophysical S-factor was calculated. The obtained results were compared with EXFOR data.

INTRODUCTION

Although nuclear power plants come to mind when it comes to nuclear physics, developments in the field of nuclear physics also contribute to the development of the health sector. Especially, radioisotopes produced in particle accelerators and reactors are frequently used in cancer treatment.

The use of radioisotopes in the biological sciences begins in 1923 with the work of von Hevesy. Hevesy has shown that the amount of radiation needed for such studies should be very small. At the time, the radioisotopes needed for such studies were not yet available. This problem was solved when Curie and Joliot discovered in 1934 that radioisotopes could be artificially produced [1].

^{124}I ($T_{1/2}$ = 4,18 day; $E_{\beta+}$ = 2,13 MeV; $I_{\beta+}$ = %22) radionuclide; It is one of the important positron emitters for nuclear medicine with its suitable uses for radio immunotherapy with Positron Emission Tomography (PET) [2].

Cross-section measurements, astrophysical S-factor calculation studies provide the opportunity to test statistical models [3].

The experimental and theoretical cross sections of the ^{121}Sb (α, n) ^{124}I reaction, which plays a particularly important role in the production of ^{124}I, were considered and half-experimental cross section values were calculated.

Astrophysical S-factor the major typical of a reaction is the cross section σ(E), which has the size of a superficial and related on energy also the cross section at stellar energies is governed by Coulomb effects. The astrophysical S-factor is defined as

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

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DOI: 10.37871/jbres1229

Submitted: 13 April 2021

Accepted: 21 April 2021

Published: 22 April 2021

Subject: Medicine Group

Topic & Subtopic(s)

- Nuclear Medicine
- Radiation Therapy

Keywords

- Radionuclide
- Cross-section
- EXFOR
- TALYS 1.8

VOLUME: 2 ISSUE: 4

How to cite this article: Yıldız E. Obtaining Astrophysical S-Factors and Half-Experimental Cross-Section Values for ^{121}Sb (α, n) ^{124}I Reaction. J Biomed Res Environ Sci. 2021 Apr 22; 2(4): 296-299. doi: 10.37871/jbres1229, Article ID: JBRES1229

where, η is the Sommerfeld parameter, $(Z_1Z_2e^2)/\hbar\nu$. The astrophysical S-factor is particularly useful in low energy regions. Empirical measurements of σ (E) at low energies measurement are mostly not available (because of the Coulomb barrier exponentially depress low-energy cross sections) [4].

MATERIALS AND METHODS

In this study, experimental values for σ(exp) ^{121}Sb (α, n) ^{124}I from ^{124}I production reactions were obtained from the EXFOR [5] database. For theoretical values, the theoretical cross-section σ(exp) values were obtained by running TALYS 1.8 [6] with the values taken from the EXFOR [5] database. In addition, NON-SMOKER [7] were used to compare values.

σ(exp) [8-13]/σ(theo)[6] a graph was drawn according to the incoming alpha energy. The polynomial fit procedure was applied on this drawn graph. The values obtained were obtained by obtaining a function dependent on energy f (E) and half-experimental cross section formula was obtained for any energy interval [14].

$$\sigma_{half-exp}.(E) = f(E).\,\sigma t_{heo}(E) \qquad (2)$$

with the polynomial fit values we obtained from figure 1, $f(E) = 41.71524-(7.37511.E) + (0.41256.E^2)-(0.00682.E^3)$ was obtained. By putting these values in place in equation number 2, figure 3 is obtained. This half-experimental cross section value obtained was compared with the theoretical values.

EXFOR

EXFOR [5] data library is a comprehensive collection of experimental nuclear reaction data, stored and reused. EXFOR web database access system; It has many services such as data search, output in various formats, drawing comparison with ENDF, rearranging old data to new standards, inverse reactions and calculating data, creating correlation matrices from partial uncertainties.

TALYS (Nuclear Reaction Code)

The TALYS 1.8 [6] 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. The mass of the target nucleus is between 5 <A≤339 and nuclear reaction calculations based on nuclear reaction models are performed with very different reaction models. Models that can be used include optical models, compound nuclear reaction models, level density models, direct reaction models, fission reaction models and pre-equilibrium reaction models [6].

Non-smoker

NON-SMOKER [7] is a computer code using the Hauser-Fesbach Model that theoretically calculates cross section values.

RESULTS AND DISCUSSION

When figure 2, was examined, it was seen that the half-experimental cross section values, especially in the range of 11-16 MeV, were compatible with the TALYS 1.8 [6] and NON-SMOKER [7,8] and [9-11] values. This harmony is especially similar to [12] and [13], TALYS 1.8 [6], NON-SMOKER [7] values after 20 MeV. Half-experimental cross section values gave very consistent results.

The astrophysical S-factor values obtained by putting the values in figure 2, in their places in equation 1 are shown in figure 3. Astrophysical S-factor values, which give valuable

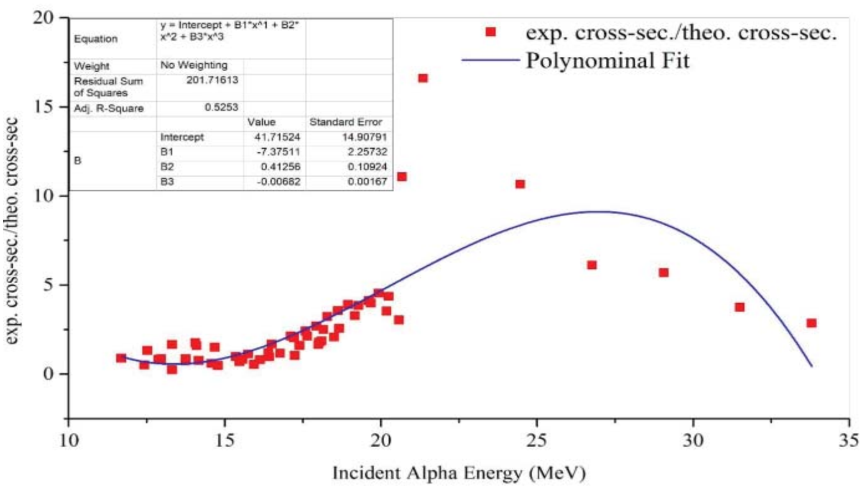

Figure 1 σ(exp)/σ(theo) and energy values polynomial fit graph.

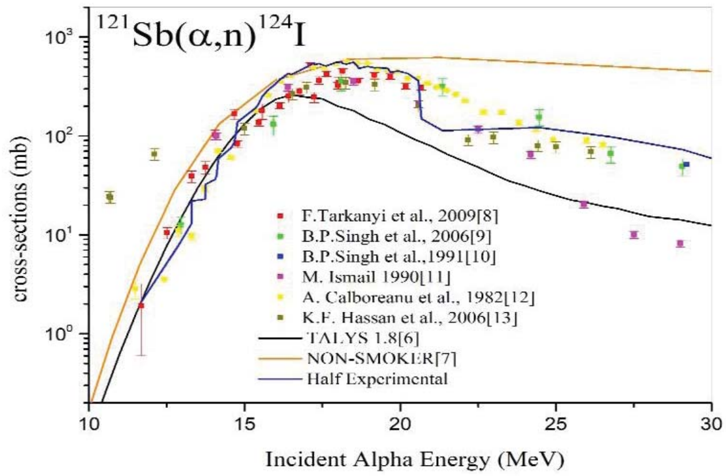

Figure 2 Cross-sectional values of the ^{121}Sb (α, n) ^{124}I reaction according to alpha energy.

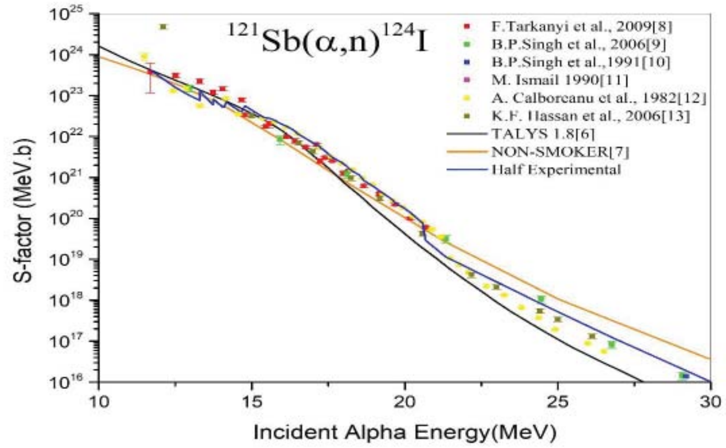

Figure 3 Astrophysical S-factor values of the ^{121}Sb (α, n) ^{124}I reaction according to alpha energy.

results especially for low energy regions, gave almost similar results when figure 3.

The half-experimental cross-section and astrophysical S-factor values we calculated in the range of 15-20 MeV, where experimental data are intense, are in great harmony. This harmony becomes more pronounced especially in the NON-SMOKER values.

It is thought that half-experimental studies will make a significant contribution especially for situations where experimental study opportunities and conditions are insufficient.

Understanding the production mechanisms and theoretical calculations of radioisotopes is important for situations where experimental studies cannot be conducted. It is believed that the half-experimental cross-section and astrophysical S-factor values that we calculated in this study will be useful for situations where these experimental studies cannot be performed. It is thought that the study will contribute to the acquisition processes of different radioisotopes, which have an important place in the field of health.

The TALYS 1.8 nuclear code program gave results consistent with the half-experimental cross-sectional values we calculated. 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 1.8 with the increase of half-experimental studies.

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.

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How to cite this article: Yıldız E. Obtaining Astrophysical S-Factors and Half-Experimental Cross-Section Values for ^{121}Sb (α, n) ^{124}I Reaction. J Biomed Res Environ Sci. 2021 Apr 22; 2(4): 296-299. doi: 10.37871/jbres1229, Article ID: JBRES1229