Study of Cross Sections for $^{10}B(n,\alpha)\,^{7}Li$ Reaction From Cross Sections of $^{7}Li(\alpha,n)^{10}B$ Reaction Using the Reciprocity Theory for the Ground State

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Abstract

In this study, light elements ^{7}Li , ^{10}B for (α,n) and (n,α) reactions as well as α-particle energy from threshold energy to 10 MeV are used according to the available data of reaction cross sections. The more recent cross sections data of (α,n) and (n,α) reactions are reproduced in fine steps 42 KeV for $^{10}B(n,\alpha)^{7}Li$ in the specified energy range, as well as cross section (α,n) Values were derived from the published data of (n,α) as a function of α-energy in the same fine energy steps by using the principle inverse reactions. This calculation involves only the ground state of ^{7}Li , ^{10}B in the reactions $^{7}Li(\alpha,n)^{10}B$, $^{10}B(n,\alpha)^{7}Li$.

Introduction

When two charged nuclei , overcome their Coulomb repulsion, a rearrangement of the constituents of the nucleus may occur. Similar to the rearrangement of atoms in reacting molecules during a chemical reaction this may result as a nuclear reaction.

Nuclear reactions are usually produced by bombarding a target nucleus with a nuclear projectile in most cases a nucleon (neutron or proton) or a light nucleus such as a deuteron or an α-particle(1) .

At low excitation energies (< 10 MeV),the majority of nuclear reactions involve the formation of two nuclei , one nearly equal in charge and mass number to the target nucleus . Such reactions are represented by an equation of the type :

$$X + a \rightarrow Y + b \quad \text{------ [1-1]}$$

Where X = target (at rest in the lab. System)
a = bombarding particle

Y = heavy reaction product
b = light reaction product

Neutron and alpha interaction

There are three principal processes resulting from the interaction of neutrons in a reaction , (scattering , radiative capture and fission). These are scattering , radiative capture and fission , each one of the three processes has its own cross section . The total cross section is the sum of these three cross section , i.e. :

$$\sigma T = \sigma s + \sigma c + \sigma f \quad \text{------[1-2]}$$

where the subscripts s , c and f refer to scattering , radiative capture and fission , respectively . The absorption cross section σa is the sum of the capture and fission cross sections i.e. $\sigma a = \sigma c + \sigma f$. In the case of non-fissionable nuclei , of course , the absorption and capture cross sections are the same (2) .Cross sections are often highly dependent on En , the energy of the incoming neutron .

Alpha interaction consists also of different types of reactions, the alpha particle interaction with target nuclei is very important also for cosmic ray studies. It represent about 10-12 percent of the primary galactic cosmic ray flux . This interaction consists of the elastic nucleus reaction, stripping, pickup and fragmentation reactions. The determination of alpha cross sections is more difficult than the other reactions due to the need of high energy alpha in order to overcome the Coulomb barrier(3).

Cross sections of nuclear reactions

To characterize the probability that a certain nuclear reaction will take place, it is customary to define an effective size of the nucleus for that reaction,which is called a cross section (1). The reaction cross section data provides information of a fundamental importance in the study of nuclear systems. The cross section is defined by (4):

$$\sigma = R / I \quad \text{------ [1-3]}$$

where σ is the cross section,
R is the number of reactions per unit time per nucleus.
I is the number of incident particles per unit time per unit area,

The cross section has the units of area and is of the order of the square of nuclear radius. A commonly used unit is the barn:

$$1 \text{ barn} = 10^{-24} \text{ cm}^2$$

The inverse nuclear reactions

In low temperatures nuclear reactions release energy with positive Q-values ,i.e.

$$1 + 2 \rightarrow 3 + 4 \qquad Q > 0 \quad \text{------ [1-4]}$$

However , as the temperature increases , the kinetic energy of nuclei are greater than the Q-values . For these particles , the following inverse process can occur

$$3 + 4 \rightarrow 1 + 2 \qquad Q < 0 \quad \text{------ [1-5]}$$

In order to fully understand and model the evolution and burning of stars and the production of heavier nuclear species, the rates for these inverse processes must be known(5) . Most of these inverse reactions process from an excited state in some, intermediate, compound system, which subsequently breaks up into the exit channel components.

Previous studies

However , substantial disagreement exists in many various cross-section measurements including those carried out on the inverse reaction $^{7}Li(\alpha,n)^{10}B$. In particular , Sealock , Wu , and Overly (6) have reported total (α,n) cross-sections about 30% higher than those of Mackline and Gibbons (7). Prompted by this discrepancy , M. D. Olson and R. W. Kavanagh had measured the $^{7}Li(\alpha,n)$ cross-section from threshold (4.382 MeV) to $E_{\alpha} = 5.67$ MeV , with results in substantial agreement with Sealock et al. except near the maximum of their energy range (8) . The reaction cross-section have been measured in KeV range directly by Ichsel and Bonner (9) Davis,Gabbard,Bonner and Bass (10) and Cox (11) and indirectly through the total cross-section by Bilpuch , Weston and Newson (12) and Diment (13) .

In addition , Bergman , Isakov , Popov and Shapiro (14) have measured the ratios of absorption cross-section of $^{6}Li(n,\alpha)$ and $^{10}B(n,\alpha)$ up to 30 KeV , and Macklin and Gibbons (15) have reported values for the ground – state branch obtained from the inverse reaction.

Results and Discussion

The cross section of (α,n) reactions for the elements ^{7}Li is available in the literature , has been taken and re-plotted for a defined energy level as shown in Fig.(1) .These plots were analyzed using the Matlab computer program to obtain the cross sections for the selected energies .

In order to calculate the cross sections of the reaction $^{10}B(n,\alpha)^{7}Li$, we adopt the cross section of the reaction $^{7}Li(\alpha,n)^{10}B$ from JENDL library(16) ,using the principle of inverse reaction .The cross section of the reaction $^{10}B(n,\alpha)^{7}Li$ was calculated and the results are plotted in Fig.(2) .It is important to note that the energy range of the reaction must be identical , For this , the determination of the energy range was done by using a fitting cubic simple available in Matlab program.

These data calculated in steps 42 KeV from (153.2 KeV) to (3.938 MeV) of the neutron energy .

Fig.(3) is the plot of the cross sections of the P.work with ENDF(17) and JENDL(16). It is clear that our result , especially , near the peak of $^{10}B(n,\alpha_0)^{7}Li$ is close to the result of ENDF rather than those of JENDL. This is due ,in our opinion to the better accuracy of ENDF for this reaction .

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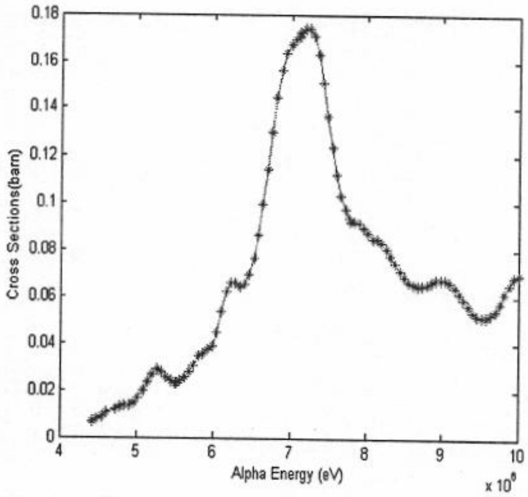

Fig.(1)The cross sections of the reaction $^{7}Li(\alpha,n)^{10}B$ as given by JENDL library - 2005

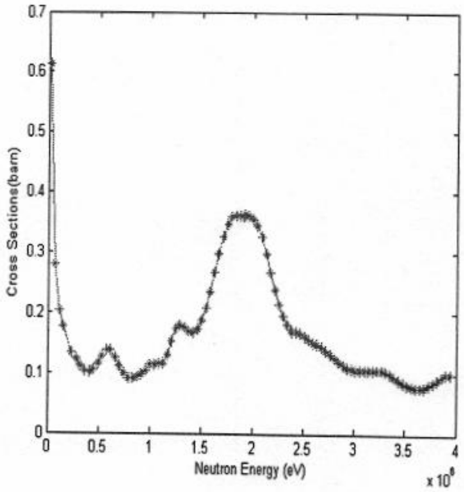

Fig.(2)The cross sections of the reaction $^{10}B(n,\alpha)^{7}Li$ as given by P.Work

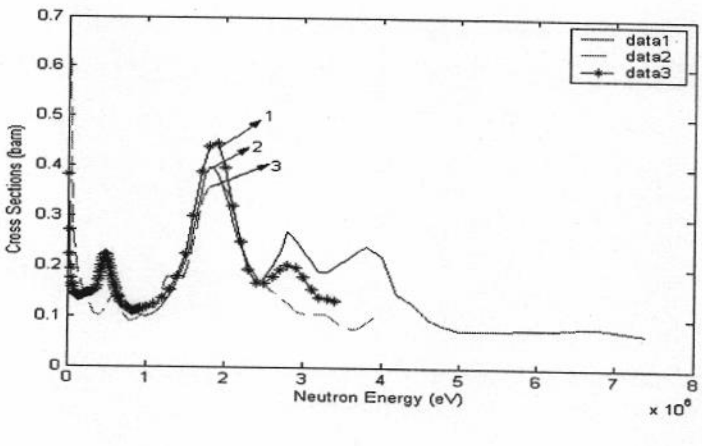

Fig.(3)The cross sections of the reaction $^{10}B(n,\alpha)^{7}Li$ Data 1 : from Jendl library -2005 Data 2 : from ENDF library Data 3 : from P.Work

دراسة المقاطع العرضية لتفاعل $^{10}B(n,\alpha)^{7}Li$ من المقاطع العرضية لتفاعل $^{7}Li(\alpha,n)^{10}B$ باستعمال نظرية التعاكس في المستوى الارضي

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الخلاصة

في هذه الدراسة ، اعيدت حسابات المقاطع العرضية للتفاعلات النووية (الفا ، نيوترون) و(نيوترون ، الفا) للنوى الخفيفة (^{10}B , ^{7}Li) حيثما توافرت البيانات و للمدى الطاقي من طاقة العتبة الى (10MeV) لجسيمات الفا والنيوترونات . ان بيانات المقاطع العرضية الاكثر حداثة للتفاعلات (الفا ،نيوترون) و(نيوترون ،الفا) قد حسبت بخطوات طاقية (42KeV) لتفاعل $^{10}B(n,\alpha)^{7}Li$، وكذلك حسبت المقاطع العرضية(الفا،نيوترون) من المقاطع العرضية (نيوترون،الفا) المنشورة في الادبيات دالة لطاقة الفا وبالخطوات الطاقية نفسها باستخدام مبدأ التفاعل المعاكس. تتضمن هذه الحسابات فقط المستوى الارضي للنوى (^{7}Li , ^{10}B) في التفاعلين $^{7}Li(\alpha,n)^{10}B$, $^{10}B(n,\alpha)^{7}Li$.