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Cross Sections Calculations of $^{33}S(n,\alpha)^{30}Si$ reaction by using the inverse reaction for the first exited state

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Abstract: In this study light elements ^{30}Si , ^{33}S for $^{30}Si(\alpha,n)^{33}S$ reaction as well as α-particle energy from (5.001) MeV to (6.284) MeV are used according to the available data of reaction cross sections with threshold energy (3.959MeV). The more recent cross sections data of $^{30}Si(\alpha,n)^{33}S$ reaction is reproduced in fine steps 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 energy in the same fine energy steps by using the principle of inverse reaction . This calculations involves the first exited state of ^{30}Si , ^{33}S in the reactions $^{30}Si(\alpha,n)^{33}S$ and $^{33}S(n,\alpha)^{30}Si$. These data are listing , plotted and dissection .

Keywords :. Cross Sections , $^{33}S(n,\alpha)^{30}Si$ reaction , inverse reaction , first exited state

Introduction

The interaction of particles with matter is described in terms of quantities known as cross sections which is defined in the following way [1]. Consider a thin target of area (a) and thickness (X) containing (N) atoms per unit volume, placed in a uniform mono-directional beam of incident particles (neutrons for example of intensity I_o) , which strikes the entire target normal to its surface as shown in fig.(1). It is found that the rate at which interactions occur within the target is proportional to the beam intensity and to the atom density, area and thickness of the target. Summarizing this experimental result by an equation, we define the interaction rate

(interaction rate)=σINaX --- (1)

Where the proportionality constant σ is known as the cross section , Thus

σ = interaction rate / INaX ---- (2)

As NaX is equal to the total number of atoms in the target, it follow that σ is the interaction rate per atom in the target per unit intensity of the incident beam [2] .

If the cross-sections of the reaction ***A(α,n)B*** is measured as a functions of T**α** (T**α** = Kinetic energy of α-particle) the cross–sections of the inverse reaction ***B(n,α)A*** can be calculated as a function of Tn (Tn = Kinetic energy of neutron) using the reciprocity theorem [3] which states that :

$$\frac{\sigma_{(\alpha,n)}}{\sigma_{(\alpha,n)}\lambda_\alpha^2}=\frac{\sigma_{(n,\alpha)}}{g_{(n,\alpha)}\lambda_n^2} \quad ---(3)$$

Where $\sigma_{(\alpha,n)}$ and $\sigma_{(n,\alpha)}$ represent cross- sections of *(α,n)* and *(n,α)* reactions respectively , g is a statistical factor and ƛ is the De–Broglie Wave Length divided by 2π and is given by

$$\lambda=\frac{\hbar}{MV} \quad -----(4)$$

Where ħ is Dirac constant (h /2π) , h is plank constant , *M* and *V* are mass and velocity of α or n particle .

Reciprocity Theory

From eq.(4),we have

$$\lambda^2=\frac{\hbar^2}{2MT} \quad -------(5)$$

Where *T* is kinetic energy

The statistical g-factors are givens by[3]

$$g_{(\alpha,n)}=\frac{2J_c+1}{(2I_A+1)(2I_\alpha+1)} \quad ---(6)$$

And

$$g_{(n,\alpha)}=\frac{2J_c+1}{(2I_B+1)(2I_n+1)} \quad ----(7)$$

The conservation law of the momentum implies that:

$$I_A + I_\alpha = J_c = I_B + I_n \quad ----(8)$$

And

$$\pi_A\pi_\alpha (-1)^{\ell\alpha} = \pi_c = \pi_B\, \pi_n(-1)^{\ell n} \quad ----(9)$$

J_c and π_c are total angular momentum and parity of the compound nucleus .

I_A and π_A are total angular momentum and parity of nucleus A.
I_B and π_B are total angular momentum and parity of nucleus B.
I_α and π_α are total angular momentum and parity of α-particle.
And
$I_n = s_n + \ell_n$ ------(12)
Where I_n is the total angular momentum of the neutron
s_n is spin of neutron = 1/2
l_n is the orbital angular momentum of neutron .
From eq.(8),we have:

$|J_c - I_A| \leq l_\alpha \leq J_c + I_A$ -----(13) And
$|J_c - I_B| \leq l_n \leq J_c + I_B$ -------(14)

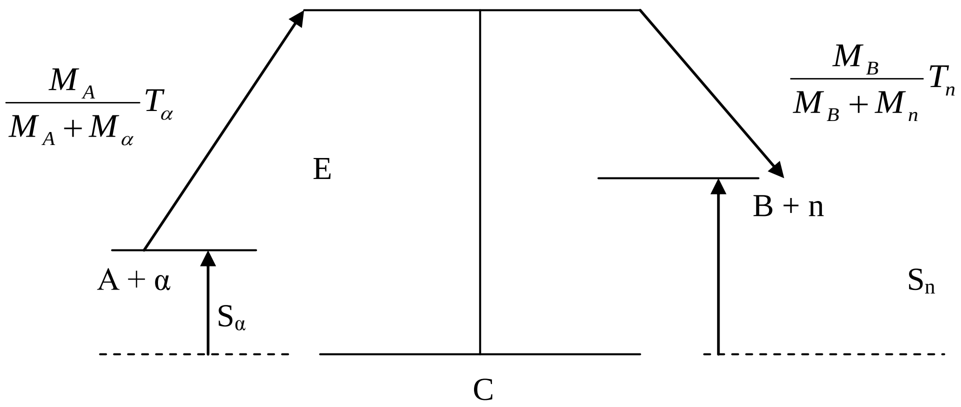
The reactions *A(α,n)B* and *B(n,α)A* can be represented with the compound nucleus C as in the following schematic diagram. It is clear that there are some important and useful relations between the kinetic energies of the neutron and alpha particle.
I_n and π_n are total angular momentum and parity of neutron .

$\pi_\alpha = \pi_n = +1$ -----(10)
$I_\alpha = s_\alpha + \ell_\alpha$ ------(11)
Where I_α is the total angular momentum of alpha particle.
s_α is spin of α-particle = 0
l_α is the orbital angular momentum of α-particle.
One can calculate the separation energies of α-particle (S_α) and neutron (S_n) using the following relations:
S_α and S_n are separation energies of α and n from C. Then

$$E = S_\alpha + \frac{M_A}{M_A + M_\alpha} T_\alpha \quad \text{---(15a)}$$

$$E = S_n + \frac{M_B}{M_B + M_n} T_n \quad \text{---(15b)}$$

With
$S_\alpha = 931.5\,[\,M_A + M_\alpha - M_c\,]$ ----(16)
$S_n = 931.5\,[\,M_B + M_n - M_c\,]$ ----(17)
Combining (15a) , (15b) , (16) and (17)



Schematic diagram of the reactions

and as the Q-value of the reaction *A(α,n)B* is given by :
Q =931.5[$M_A + M_\alpha - M_B - M_n$] ---(1-18)
Then

$$Q = \frac{M_B}{M_B + M_n} T_n - \frac{M_A}{M_A + M_\alpha} T_\alpha \quad \text{----(19)}$$

Or :

$$T_n = \frac{M_B + M_n}{M_B}\left[\frac{M_A}{M_A + M_\alpha} T_\alpha + Q\right] \quad \text{----(20)}$$

The threshold energy E_{th} is given by :

$$E_{th} = -Q\frac{M_A + M_\alpha}{M_A} \quad \text{---(21a)} \quad \text{Or}$$

$$Q = -\frac{M_A}{M_A + M_\alpha} E_{th} \quad \text{---(21b)}$$

Then

$$T_n = \frac{M_B + M_n}{M_B} \times \frac{M_A}{M_A + M_\alpha}(T_\alpha - E_{th}) \quad \text{---(22)}$$

Thus eq.(3) can be written as follows :

$$\sigma_{(n,\alpha)} = \frac{g_{(n,\alpha)} M_\alpha T_\alpha}{g_{(\alpha,n)} M_n T_n}\ \sigma_{(\alpha,n)} \quad \text{----(23)}$$

It is clear from this equation that the cross sections of reverse reaction are related by a variable parameters which can be calculated if the nuclear characteristics of the reactions are known.

Results and Discussion

The atomic mass of elements and isotopes mentioned in this study have been taken from the latest (1995) nuclear wallet cards released by the National Nuclear Data Center(NNDC) [4] and abundances are given for stable isotopes from reference International Atomic Energy Agency (IAEA) [5]. The energy level, parity and spin scheme of isotopes used in the present work is given in table(1) [6].

Table (1):Energy level, spin and parity of isotopes(^{33}S and ^{30}Si)[6]

Level scheme of ^{33}S			Level scheme of ^{30}Si		
Level	Energy (MeV)	Spin & parity	Level	Energy (MeV)	Spin & parity
G.S.	0.0	$3/2^+$	G.S.	0.0	0^+
1st	0.841	$1/2^+$	1st	2.127	2^+
2nd	1.967	$5/2^+$	2nd	3.304	2^+
3rd	2.313	$3/2^+$	3rd	3.916	0^+
4th	2.867	$5/2^+$	4th	4.074	1^+
5th	2.935	$7/2^-$	5th	4.114	2^+
6th	2.968	$7/2^+$	6th	4.624	3^-

The cross sections of $^{30}Si(\alpha,n)^{33}S$ reaction have been, calculated in fine steps from (5.001) MeV to (6.284) MeV of α-particle energy by Flynn D.S. , Sekharan K.K. , Hiller B.A., Laumer H. and Weil J.L. [7] these data are plotted in Fig.(2).

By using the compound theory we derive the mathematical formula for $^{33}S(n,\alpha)^{30}Si$ reaction by first exited state :

$$\sigma_{n,\alpha} = 1.653 \frac{T_\alpha}{T_n} \sigma_{\alpha,n} \qquad \text{--------- (24)}$$

The evaluated cross sections as a function of neutron energy from (0.9468) MeV to (2.1133) MeV of present work are listed in tables (2). These data are plotted in Fig.(3) and we do not get equation for distribution because there are resonance and we get the maximum cross section to produce the ^{30}Si by neutron energy (1.4123) MeV is (1508.0) mbarn. ^{30}Si is very important in technology field. In Fig.(3) we observed that the high probability to produce ^{30}Si in fast neutron which (1.6878) MeV and (2.0860) MeV are (1116.4) mbarn and (1192.4) mbarn respectively.

In figure (4) the cross sections as a function of neutron energy by Wagemans C. , Weigmann H. , Barthelemy R.[8] , we observed that the high probability to produce ^{30}Si by bombard ^{33}S by (0.9489MeV) is (66.55mbarn) .

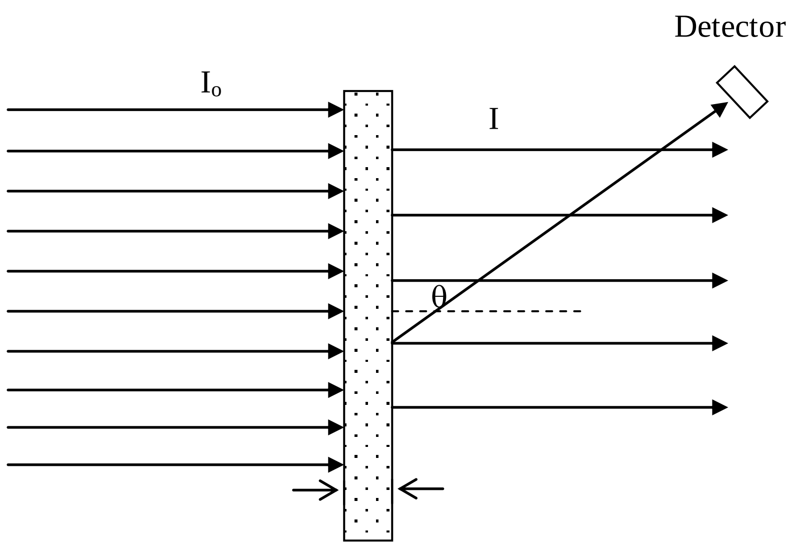


Figure (1): A schematic diagram illustrating the definition of total cross section in terms of the reduction of intensity[1].

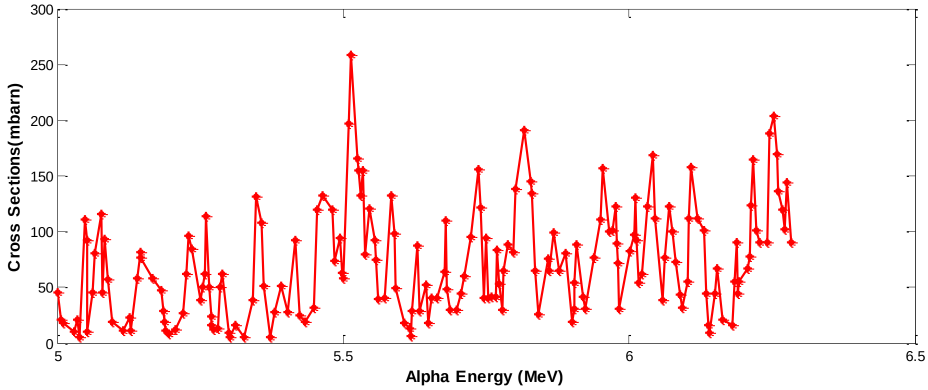


Fig.(2): Cross sections of 30Si(α,n)33S reaction [7]

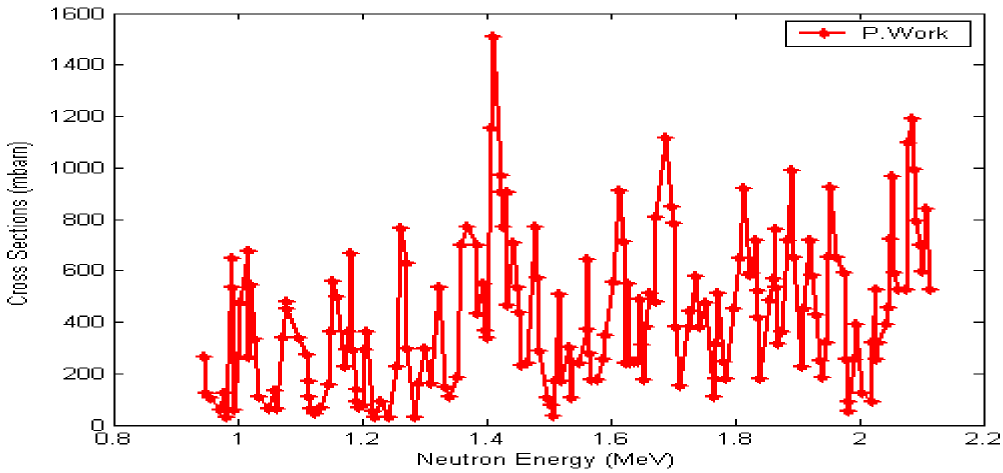


Fig.(3): Cross sections of 33S (n,α)30Si reaction p.work

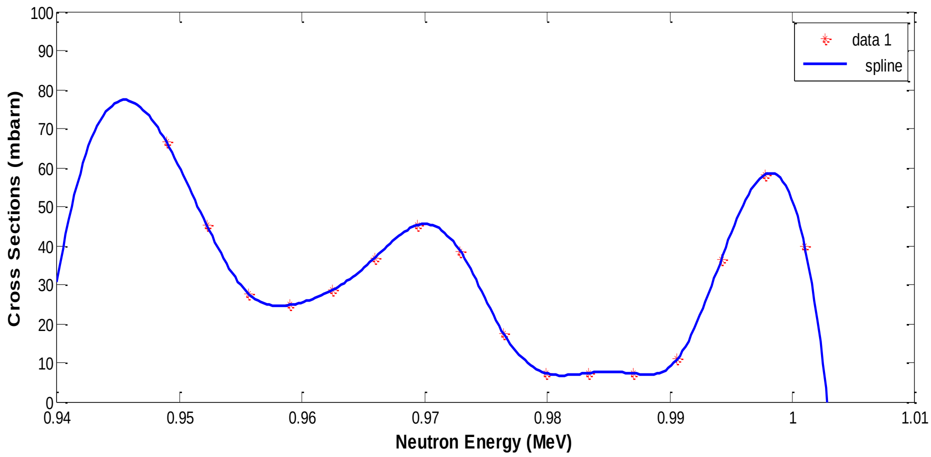


Fig.(4): Cross sections of 33S (n,α)30Si reaction [8]

Table (2):The cross sections of $^{33}S(n,\alpha)^{30}Si$ reaction as a function of neutron energy present work

neutron -energy (MeV)	X- sections (mbarn)P.Work	neutron -energy (MeV)	X- sections (mbarn)P.Work	neutron -energy (MeV)	X- sections (mbarn)P.Work
0.9468	263.0	1.1805	362.4	1.4251	906.0
0.9514	122.7	1.1823	666.3	1.4278	771.5
0.9550	105.2	1.1869	292.3	1.4323	906.0
0.9723	058.5	1.1905	140.3	1.4351	467.6
0.9787	122.7	1.1914	93.50	1.4423	707.2
0.9814	029.2	1.1941	70.10	1.4505	537.7
0.9905	648.8	1.2023	76.00	1.4533	438.4
0.9932	537.7	1.2050	292.3	1.4569	233.8
0.9941	58.50	1.2087	362.4	1.4669	239.6
1.0014	263.0	1.2187	52.60	1.4778	771.5
1.0059	473.4	1.2214	29.20	1.4814	572.8
1.0168	678.0	1.2296	93.50	1.4842	286.4
1.0178	263.0	1.2423	29.20	1.4978	105.2
1.0205	543.6	1.2578	228.0	1.5060	076.0
1.0268	333.2	1.2623	765.7	1.5087	35.10
1.0341	111.1	1.2714	631.3	1.5105	169.5
1.0514	64.30	1.2741	298.1	1.5178	508.5
1.0605	134.4	1.2851	29.2	1.5223	169.5
1.0623	64.30	1.2914	163.7	1.5333	303.9
1.0732	339.0	1.3014	298.1	1.5360	105.2
1.0778	479.3	1.3123	163.7	1.5405	239.6
1.0787	450.1	1.3241	537.7	1.5496	239.6
1.0978	339.0	1.3323	146.1	1.5614	374.1
1.1114	274.7	1.3405	111.1	1.5633	643.0
1.1141	169.5	1.3541	187.0	1.5660	280.6
1.1159	111.1	1.3596	701.4	1.5705	175.4
1.1178	64.3	1.3678	771.5	1.5805	175.4
1.1232	46.8	1.3842	701.4	1.5887	257.2
1.1341	70.1	1.3869	432.5	1.5933	350.7
1.1469	157.8	1.3951	549.4	1.6033	555.3
1.1505	362.4	1.3987	368.2	1.6160	911.8
1.1541	561.1	1.4014	339.0	1.6196	713.1
1.1605	496.8	1.4096	1151.5	1.6242	239.6
1.1741	228.0	1.4123	1508.0	1.6278	549.4
1.1769	292.3	1.4232	970.3	1.6315	239.6
1.6360	245.5	1.8397	181.2	2.0442	391.6
1.6442	245.5	1.8569	485.1	2.0479	455.9
1.6460	491.0	1.8633	567.0	2.0497	724.8
1.6487	309.8	1.8651	759.9	2.0524	964.4
1.6533	175.4	1.8669	537.7	2.0579	590.3
1.6551	379.9	1.8697	315.6	2.0624	526.1
1.6633	514.4	1.8760	362.4	2.0742	526.1
1.6715	479.3	1.8842	718.9	2.0779	1098.9
1.6742	806.6	1.8924	987.8	2.0860	1192.4
1.6878	1116.4	1.8960	654.6	2.0897	993.7
1.6987	847.5	1.9088	228.0	2.0915	794.9
1.7015	783.2	1.9115	450.1	2.0997	701.4
1.7051	379.9	1.9197	718.9	2.1024	596.2
1.7105	152.0	1.9233	584.5	2.1070	841.7
1.7269	444.2	1.9297	426.7	2.1133	526.1
1.7287	379.9	1.9369	251.3	----	----
1.7360	578.7	1.9397	187.0	----	----
1.7433	379.9	1.9478	321.5	----	----
1.7542	473.4	1.9506	654.6	----	----
1.7651	111.1	1.9533	923.5	----	----
1.7678	181.2	1.9642	654.6	----	----
1.7687	315.6	1.9751	590.3	----	----
1.7724	514.4	1.9778	257.2	----	----
1.7824	245.5	1.9815	93.5	----	----
1.7860	181.2	1.9833	52.6	----	----
1.7987	450.1	1.9915	257.2	----	----
1.8097	648.8	1.9960	391.6	----	----
1.8133	917.7	2.0033	122.7	----	----
1.8233	584.5	2.0197	93.5	----	----
1.8287	590.3	2.0224	321.5	----	----
1.8333	718.9	2.0260	526.1	----	----
1.8360	520.2	2.0279	257.2	----	----
1.8369	420.8	2.0306	321.5	----	----

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حساب المقاطع العرضية للتفاعل $^{33}S(n,\alpha)^{30}Si$ بأستخدام التفاعل المعاكس للمستوى المتهيج الأول

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الخلاصة

في هذه الدراسة اعيد حساب المقاطع العرضية للنوى الخفيفة 33S , 30Si للتفاعل 30Si(α,n)33S للبيانات المتوفرة في الادبيات العالمية وللمدى الطاقي من MeV (5.001) الى MeV (6.284) وبطاقة عتبه مقدارها (3.959MeV) كدالة للمقاطع العرضية . بأستخدام نظرية التعاكس اذ اشتقت معادلة لحساب المقاطع العرضية لتفاعل 33S(n,α)30Si وللمستو المتهيج الاول وذلك بالاعتماد على المقاطع العرضية لتفاعل 30Si(α,n)33S ومن ثم الحصول على معادلة للرسم البياني من خلال استخدام برامج الحاسوب (Matlab-6.5) . تم رسم وجدولة النتائج بالاضافة الى مناقشة النتائج.