A DWBA analysis of the $^{7}Li(^{3}He,\alpha)^{6}Li$ reaction in the ^{3}He energy range 1.81 to 5.13 MeV

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Abstract

The angular distributions of the α- particles from the reaction $^{7}Li(^{3}He,\alpha)^{6}Li$ measured in the ^{3}He energy range 1.81 to 5.13 MeV were analyzed in terms of the DWBA theory . Zero range DWBA was used without radial cut-off . Absolute spectroscopic factors were obtained and compared with the shell model calculations.

1. Introduction

The angular distributions of the α- particles from the $^{7}Li(^{3}He,\alpha)^{6}Li$ reaction have been measured by different authors in the ^{3}He energy range 1.o to 27.o MeV [1 - 7] . DWBA calculationa were carried out at ^{3}He energies between 5.o and 18.o MeV [6 , 7] . In the present work, the experimental angular distributions of the α- particles from the $^{7}Li(^{3}He,\alpha)$ ^{6}Li reaction measured by P.D.Forsyth et al [2] at ^{3}He energies between 1.81 and 5.13 MeV were analyzed in terms of the DWBA theory.

2. DWBA analysis

DWBA calculations in the usual zero range approximation without radial cut-off were carried out on the Univac 1100 computer of the Institute of Nuclear Physics, Frankfurt, Deutchland-Germany using the code DWUCK due to Kunz [8]. The potentia used has the form:

$$V(r) = V_0(r) + V\, f(x) + i\, W\, f(x_i) - V_s \frac{1}{r} \frac{d}{dr} f(x)\, \vec{L}.\vec{S} \qquad (1)$$

$$\text{where } f(x) = \left[1 + \exp \frac{(r - r_o A^{1/3})}{a} \right]^{-1}$$

$$f(x_i) = \left[1 + \exp \frac{(r - r_i A^{1/3})}{a_i} \right]^{-1}$$

The Coulomb potential was assumed to be that of a uniformly charged sphere of radius $R_c = r_c A^{1/3}$. The neutron was assumed to be captured in a potential well of the Saxon - Woods form with the spin-orbit potential of the Thomas type. The well depth parameter was adjusted by the code to give the proper neutron binding energy. The optical model parameters are collected in Table 1. ~~All the~~ Previous ^{3}He and the α-particle parameters were tried in the present analysis. It is found however that the results of the analysis are sensitive to the choice of the optical model parameters. Satisfactory fits with reasonable spectroscopic factors were obtaine with optical model parameter set BC deduced from the general optical model potent-ials present in ref.[9]. The results of the analysis are shown in figs. 1, 2 , 3 The spectroscopic factors were calculated by using the formula:

$$C^2 S = \frac{1}{N^2} \frac{2(2j+1)}{2s+1} \frac{\sigma_{exp.}(peak)}{\sigma_{DW}(peak)} \qquad (2)$$

where s is the spin of the captured neutron,
j is the total angular momentum of the captured neutron,
$\sigma_{exp.}$ is the experimental reaction cross-section at the peak,
σ_{DW} is the calculated cross-section at the peak,

2 is a normalization factor and its value in the case of $(^3He, \alpha)$ reactions = 25.o

2 = $(T_o t, M_{T_o}, M_t \; T M_T)^2$ is the square of the Clebsch-Gordan coefficient for isobaric-spin coupling [10], where T_o, T and t are the isobaric- spin quantum numbers of the ^6Li final state, ^7Li initial state and of the transfered neutron respictively, and M_{T_o}, M_T, M_t are their Z - components. In the case of the reaction $^7Li(^3He, \alpha_o)^6Li$, $C^2 = 1$ for T = o states and $C^2 = 1/3$ for T = 1 states.

ne spectroscopic factors are given in Table 2. Theoretical spectroscopic facors have been calculated by S.Cohen et al [14] and by S.Varma et al [15]. S. ohen et al listed separate components for $1p_{3/2}$ and $1p_{1/2}$ transfers, but S.Varma : al gave only the sum. The experimental spectroscopic factors for 1p transfers otained in the present work were evaluated as though they arose entirely from $p_{3/2}$ transfers or, if allowed entirely from $1p_{1/2}$ transfers. The spectroscopic factors educed in the present work are generally higher than the theoretical predictions.

. Conclusions

ie results of the prosent analysis are sensitive to the choice of the optical odel parameters. However, the general formulae of the optical model potentials ven in ref. [9] seem to be applicable to the case of the interactions of ^3He th light nuclei at low energies [11]. The fits obtained in the present work or the different α- groups from the $^7Li(^3He,\alpha)^6Li$ reaction at the ^3He energ- es under consideration are generally good at forward angles. The lack of obtaing better fits in the case of the α_o and α_2 groups at backward angles is attbuted to an exchange mechanism in which the α-particle comes directly from the arget nucleus, the ^3He being captured [3], while the lack of obtaining better fito the case of the α_1 group may be attributed to the compound nucleus effects.

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Figure captions

Fig.1 DWBA fits to the angular distributions of the α_0 - group at the ^3He energies 4.36 and 5.13 MeV. Dots are the experimental results taken from ref. [2]. Solid lines are the DWBA calculations in the usual zero range approximation without radial cut-off using the optical model parameter set BC present in Table 1 .

Fig.2 DWBA fits to the angular distributions of the α_1 - group from the reaction $^7Li(^3He,\alpha)^6$ Li at ^3He energies between 1.81 and 2.98 MeV. Dots are the experimental results taken from ref. [2]. Solid lines are the DWBA calculations in the usual zero range approximation without radial cut-off using the the optical model parameter set BC present in Table 1.

Fig.3 DWBA fits to the angular distribution of the α_2 - group from the reaction $^7Li(^3He,\alpha)^6Li$ at E_{3He} = 4.36 MeV. Dots are the experimental results taken from ref. [2]. Solid line represent the DWBA calculations in the usual zero range approximation without radial cut-off using the optical model parameter set BC present in Table 1 .

Table [illegible] Optical model [illegible]

Reaction channel	Ref.	V (MeV)	r_0 (fm.)	a_0 (fm.)	[illegible]	r_i (fm.)	a_i (fm.)	V_s (MeV)	r_s (fm.)	a_s (fm.)	r_c (fm.)
A Helium-3	[12]	140.0	[illegible]	[illegible]	[illegible]	[illegible]	0.75	12.0	1.20	0.70	1.3
B Helium-3	[9]	[illegible]	1.60	0.65	[illegible]	1.60	0.65				1.6
C Helium-4	[9]	40.0	1.70	0.65	12.0	1.70	0.65				1.7
D Helium-4	[13]	189.4	1.92	0.60	7.7	1.92	0.60	11.1	1.92	0.60	1.4

Table 2 Spectroscopic factors

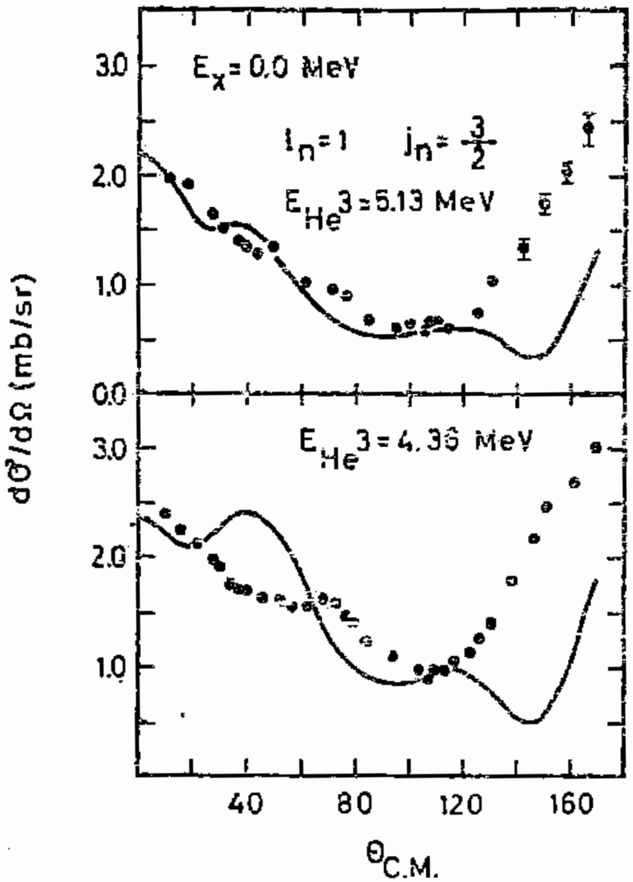
E_{He3} (MeV)	$S_{exp.}$ (pres. work) α_0 a) $j_n=3/2$	$j_n=1/2$	α_1 b) $j_n=3/2$	α_2 c) $j_n=3/2$	α_0 d) $j_n=3/2$	$j_n=1/2$	$S_{th.}$ [14] α_1 $j_n=3/2$	α_2 $j_n=3/2$	$S_{th.}$ [15] α_1	α_2
5.13	1.07 or	1.14			0.43	0.29				
4.36				1.12				0.89		0.75
≈2.98			1.37				0.55		0.35	
2.50			1.29							
2.14			1.04							
1.81			1.12							

a) α_0 corresponds to the ground state in ^6Li with $(J^\pi,T) = 1^+,0$.

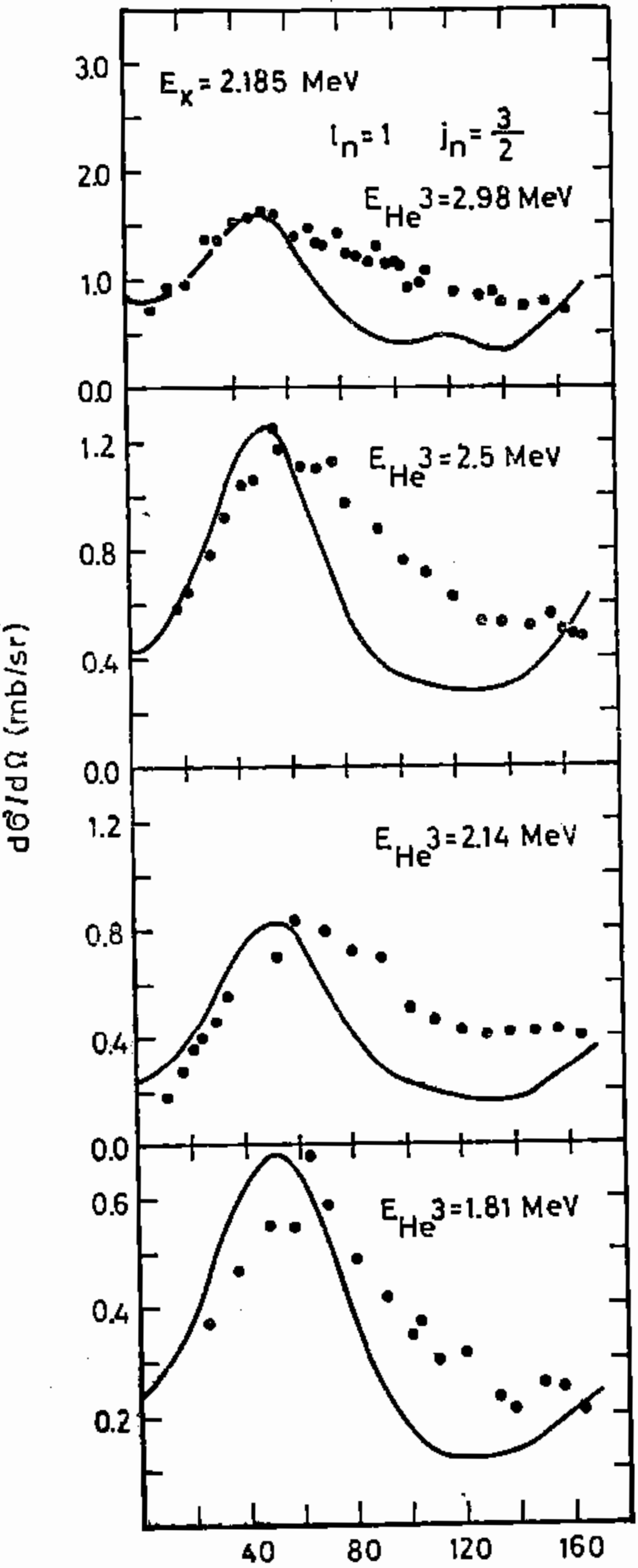
b) α_1 corresponds to the excited state of E_x = 2.185MeV in ^6Li and $(J^\pi,T) = 3^+,0$.

c) α_2 corresponds to the excited state of E_x = 3.55 MeV in ^6Li and $(J^\pi,T) = 0^+,1$.

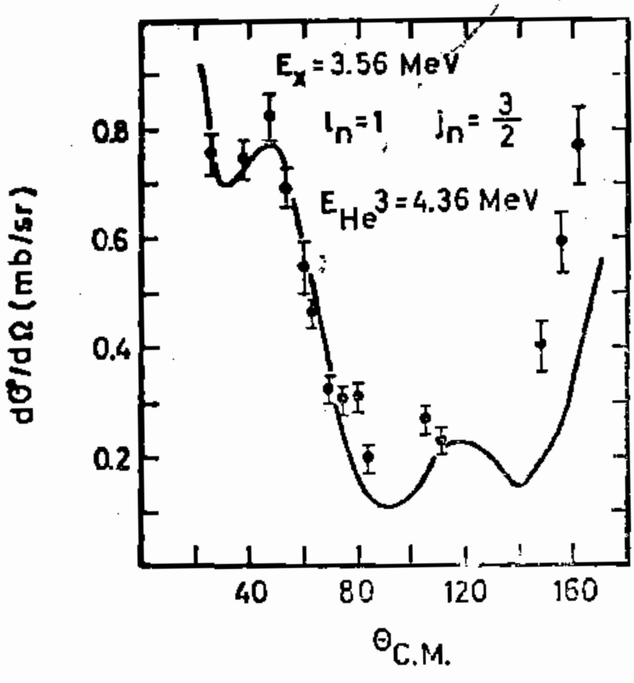
d) $l_n = 1$ for all the three α- groups.



E_x = 0.0 MeV
l_n = 1 $j_n = \frac{3}{2}$
E_{He^3} = 5.13 MeV
E_{He^3} = 4.36 MeV
$d\sigma/d\Omega$ (mb/sr)
$\Theta_{C.M.}$
3.0
2.0
1.0
0.0
40
80
120
160



$E_x = 2.185$ MeV
$l_n = 1$ $j_n = \frac{3}{2}$
$E_{He^3} = 2.98$ MeV
$E_{He^3} = 2.5$ MeV
$E_{He^3} = 2.14$ MeV
$E_{He^3} = 1.81$ MeV
$d\sigma/d\Omega$ (mb/sr)
3.0
2.0
1.0
0.0
1.2
0.8
0.4
0.0
1.2
0.8
0.4
0.0
0.6
0.4
0.2
40
80
120
160


$E_x = 3.56$ MeV
$l_n = 1$ $j_n = \frac{3}{2}$
$E_{He^3} = 4.36$ MeV
0.8
0.6
0.4
0.2
$d\sigma/d\Omega$ (mb/sr)
40
80
120
160
$\Theta_{C.M.}$

تحليل نتائج التفاعل ليثيوم^{٧} (هيليوم^{٣} ،ألفا) ليثيوم^{٦} الناتجه عن فترة الطاقه ١٨ر١ الى ١٣ر٥ مليون الكترون فولت باستخدام نظريه الموجه المشوهه.

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الملخص :

فى هذا البحث تم تحليل نتائج التوزيع الزاوى لجسيمات الألفا الصادره من التفاعل ليثيوم^{٧} (هيليوم^{٣} ، ألفا) ليثيوم^{٦} والمقاسه عن فترة الطاقه ١٨ر١ الى ١٣ر٥ مليون الكترون فولت وذلك باستخدام نظريه الموجه المشوهه . ولقد أستخدم فى ذلك معاملات ضوئيه مختلفه للهيليوم^{٣} والألفا . وقورنت النتائج التى تم الحصول عليها من هذا ونقارن بالحسابات النظريه .