MEASUREMENTS OF GROUND, FIRST EXCITED-STATE ENERGY AND WIDTH OF ^{5}He VIA d-^{7}Li REACTION

[1]Baykal Adnan, [1]Tarcan Gökçe, [1]Reyhancan Iskender Atilla and [2]Erduran M. Nizamettin

[1]Çekmece Nuclear Research and Training Centre, Department of Physics, P.O.Box.1, Atatürk Airport, TR-34831, Istanbul-TURKEY
[2]University of Istanbul, Faculty of Science, Department of Physics, Vezneciler 34459 Istanbul-TURKEY

Abstract

The reaction products from d-^{7}Li were studied using a 150 keV deuteron beam from SAMES J-15 accelerator at Çekmece Nuclear Research and Training Centre (ÇNAEM). The target was obtained by evaporating natural LiF (800μg/cm^{2}) onto Aluminium backing (1500μg/cm^{2}). Two silicon surface barrier detectors (SSB) were chosen in order to detect all the alpha-particles produced in the reaction and they were placed on the opposite side respect to the beam. The alpha-alpha coincidence technique was employed and energy signals from SSB#2 detector placed on 83.5^{0} are gated with 6.7 - 8.2 MeV interval of energy signals from SSB#1 placed on 90^{0} . Coincidence spectra obtained were corrected for the energy loss in the target. The coincidence spectra were then unfolded and alpha lines belonging to the ground and first excited states of ^{5}He were then identified.

1. Introduction

Up to now, the ground state width of ^{5}He is measured by a few laboratories. Measured values are range of 0.525 and 1.36 MeV [1]. In last measured data [2], the values of excitation energy and width are 0.80±0.02 MeV and 0.65±0.02 MeV for ground state via ^{3}H(d,γ)^{5}He reaction respectively.

Although first excited state of ^{5}He is also measured by a lot of laboratories, there are discrepancies between reported values[3]. These values are range 1.97-5.2 MeV and 1.5-7 MeV for excitation energy and width of first excited state respectively. Evaluated values for ground state width, energy of the first excited state and state width are 0.6±0.02 MeV, 4.0±1.0 MeV 4.0±1.0 MeV respectively [4].

2. Experimental Set-up

The scattering reaction chamber is a cylinder shape of 25.4 cm diameter, 10 cm height and has vacuum 10^{-6}torr. It is coupled SAMES J-15 low energy ion accelerator (E_d=150keV). Two silicon surface barrier detectors (SSB) are chosen in order to detect all the alpha particles produced in the reaction and they are placed on the opposite side respect to the beam. First one (SSB#1) is fixed at 90^o and the other one (SSB#2) has changeable angular movement (0-360 degrees) (Figure 1). Both of the detectors have collimators of 8 mm in diameter and 10 mm in length. The specifications of SSB detectors are energy resolution <14 keV and depletion layer 300μm.

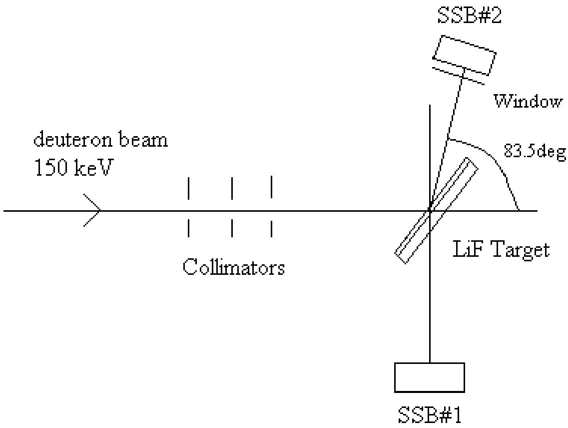

Figure 1. Experimental Setup

Unanalysed deuteron beam (76% atomic and 24% molecular) before Li target passes through the three separate collimators of 18 cm length and 3 mm diameter. Li target is placed 45^o with respect to the beam. Due to the deuteron scattering on the target, the SSB#2 detector faced to the Li target has a window made of Aluminum-Mylar of 850 μg /cm^2. SSB#1 has no such a window because it is placed opposite side respect to the beam and behind the Li target.

Thin Li targets are produced with coating LiF (800μg/cm^2) on the Aluminum substrate (1500μg/cm^2) by evaporation method in the vacuum chamber (~10^{-4}Torr). During the irradiation, deuteron current is measured 10 μA on the target. Experimental set-up is shown Figure 1 and electronic setup is also seen Fig.2.

3. Kinematics of Reaction

d-Li reaction is formed three different channels. These channels are direct reaction ^{7}Li(d,αα)n, disintegration of ^{5}He via ^{7}Li(d,α) ^{5}He(α)n and disintegration of ^{8}Be via ^{7}Li(d,n)^{8}Be(α)^{4}He.

The contribution of disintegration of ^{5}He is higher than other two reactions in estimated spectra, the sum of contributions of other two reactions are also less than 10% [5]. Using direct reaction kinematics formula [5], energy diagram of α_1 and α_2 particles is obtained as shown Figure 3 (Dalitz Diagram) for a given bombarding energy E_d = 150 keV and two angles of detection angles $\theta_1 = 90^o$, θ_2 = 60,75,83.5, 90 and 95 degrees.

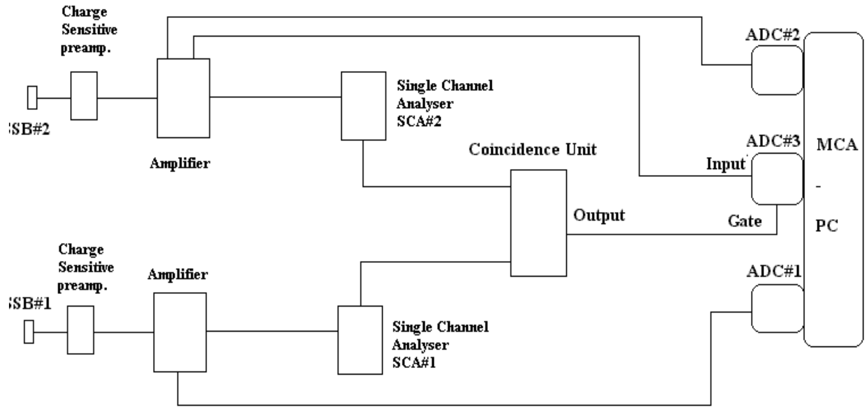

Figure 2. Block diagram of electronics

When knowing the energy of alpha particles detected by coincidence spectra from SSB detectors experimentally, corresponding the ground and first excited states of ^{5}He nucleus (J^π =3/2$^-$, 1/2$^-$ respectively) and the ground and excited states of ^{8}Be nucleus (0^+, 2^+ and 4^+ respectively) can be found with help of this diagram. At the same time, energies of alpha particles which are found by changing E_x excitation energy of ^{5}He nucleus (E_x (^{5}He)=0 - 9 MeV) are shown at Fig. 4.

4. Analysis and Results

The charge particle energy spectra collected from SSB#1 (θ_1=90^0) and SSB#2 (θ_2=83.5^0) detector are shown in Figure5. At the same time, in this spectra, Coincidence spectra is taken at SSB#2 detector for θ_2=83.5^0 (0-13 MeV) gated by consecutive energy window of the SSB#2 detector for θ_1=90^0 over the energy range 6.7-8.2 MeV.

Energy calibration for SSB#1 is made with help of mixed alpha source (5.142, 5.484, 5.808 MeV at Pu-239, Am-241, Cm-244 respectively), protons from the reaction ^{2}H (d,p)^{3}H and alphas from the reaction ^{6}Li(d,α)^{4}He. The reactions ^{2}H (d,p)^{3}H, ^{6}Li(d,α)^{4}He and ^{6}Li(d,p)^{7}Li are used for energy calibration of SSB#2 detector.

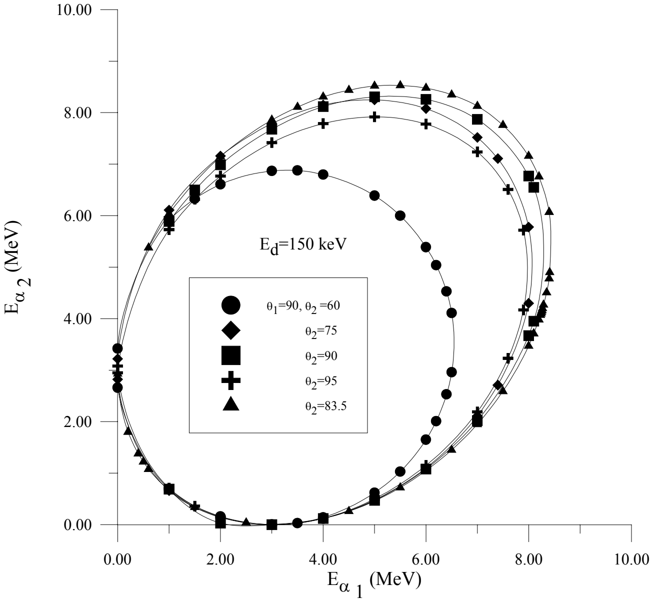

Figure 3. Dalitz Diagram

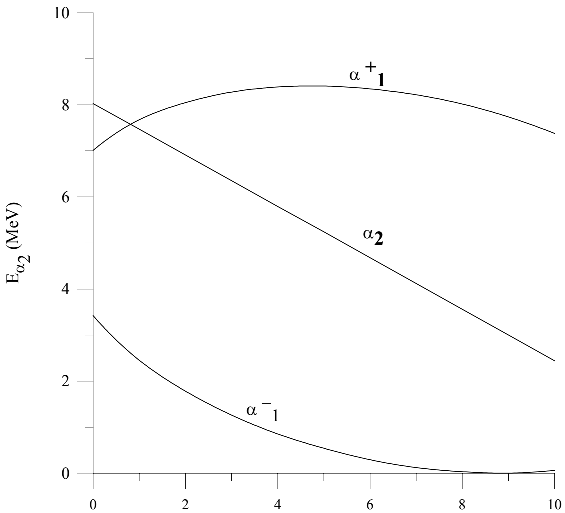

Figure 4. Energetics of ^{5}He formation

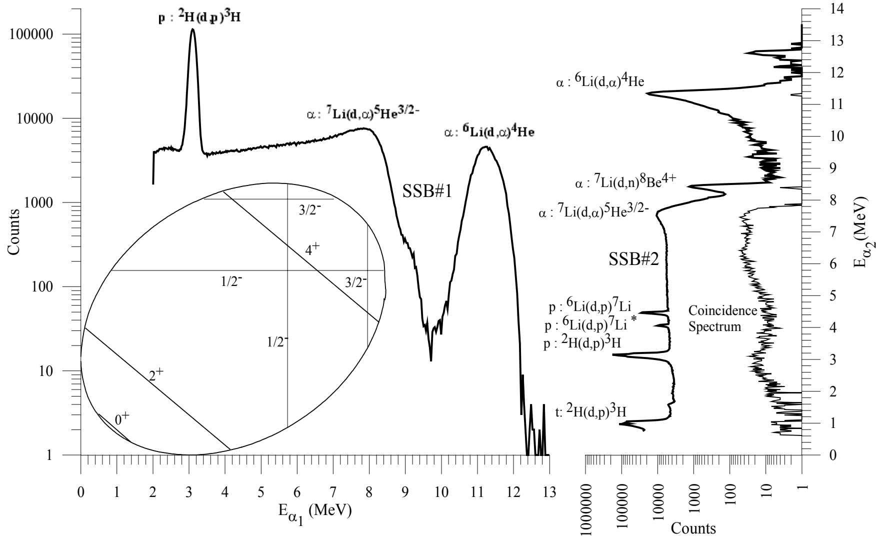

Figure 5. Alpha energy and Coincidence Spectrum

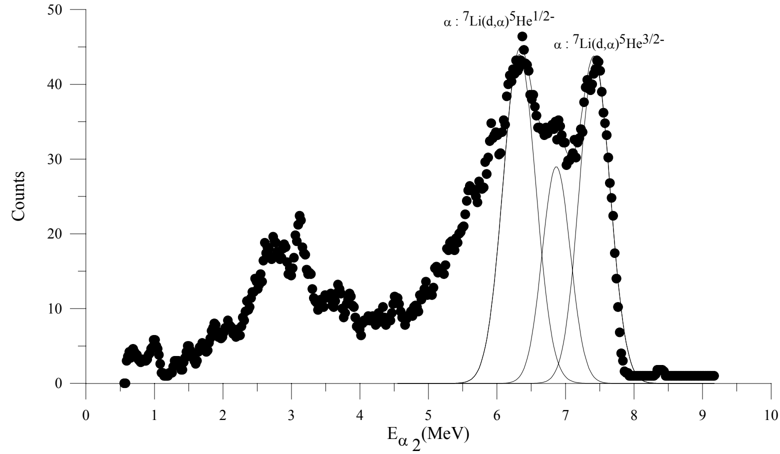

Figure 6. Smoothed Coincidence Spectrum

Because the SSB#1 detector is behind the Li target and Aluminum foil in front of SSB#2 detector is used for eliminating noise (deuteron scattering), energy loss for charge particles must be corrected. Coincidence spectrum is smoothed for analyzing by 5-point zeroth order smooting method (Figure 6). The calculated energy values for the ground and first excited states of ^{5}He using Figure 4 are shown below.

$E_x(^5He^{3/2-}) = 1.0\pm0.4$ MeV, $\Gamma(^5He^{3/2-}) = 0.5\pm0.2$ MeV
$E_x(^5He^{1/2-}) = 3.0\pm0.5$ MeV, $\Gamma(^5He^{1/2-}) = 0.6\pm0.2$ MeV

5. Discussion

The alpha energies of the ground and first excited states of ^{5}He are measured at the coincidence spectrum well. Measured alpha energy values are fitted with theoretical Dalitz Diagrams for the ground and first excited states of ^{5}He nucleus. Uncertainties of the width and energy values are higher than other literature data, because the data collection time is not enough for a good statistics during the data taking, although the time is 131000 sec and so long. Additionally, the ^{7}Li(d,α)^{5}He reaction cross section for 150 keV deuteron energy is so low (0.15 mb). If the reaction experiment is done with analyzed 300 keV deuterons, because of higher reaction cross section (1.5 mb) [6], we can get a good counting statistics.

References

1. M.J. Balbes, G. Feldman, L.H. Kramer and H.R. Weller, Phys. Rev. C, Vol. 43, Num. 1, (1991), 343-346.
2. V.D. Efros and H. Oberhummer: Physical Review C, Vol. 54, Num. 3, (1966), 1485-1487.
3. N. Arena et al.: Journal of the Physical Society of Japan Vol. 60.No.1, (1991), 100-106.
4. F. Ajzenberg-Selove: Nuclear Physics. A 490. (1988). 1- .
5. P.A. Assimakopoulos, N.H. Gangs and S. Kossionides : Nuclear Physics 81, (1966), 305-321.
6. M. Manalis and J.E. Henkel. Physical Reviev. Vol. 136. Number 6B. (1964), B 1741-B1743.