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^{7}Li + ^{3}He REACTION AT LOW ^{3}He ENERGY

D. M. STANOJEVIĆ, M. R. ALEKSIĆ, B. Z. STEPANČIĆ and R. V. POPIĆ

Institute of Nuclear Sciences "Boris Kidrič", Beograd

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Abstract: The reactions ^{7}Li (^{3}He, p) ^{9}Be and ^{7}Li (^{3}He, d) ^{8}Be are investigated in order to study the reaction mechanism and to extract data concerning the $E_{^3He} = 1.1$ MeV resonance in ^{10}B. The excitation curves for the p_0, p_2 and d_0 groups and the angular distributions of the p_0, p_2, p_3 and d_0 groups show that: (*i*) the ^{7}Li (^{3}He, p) ^{9}Be reaction proceeds via a ^{10}B compound state at $E_x = 18.5$ MeV with $\Gamma = 100 - 400$ keV, $J^\pi = 2^-$ and $T = 1$; the nearest state at 18.8 MeV is most probably a 2^+ state; (*ii*) the ^{7}Li (^{3}He, d) ^{8}Be reaction proceeds via a direct stripping mechanism.

1. Introduction

In ^{10}B several resonances occur above the ^{7}Li + ^{3}He threshold at 17.786 MeV. In the ^{7}Li (^{3}He, γ) ^{10}B and ^{7}Li (^{3}He, α) ^{6}Li reactions, Paul et al.$^{1, 2)}$ have found resonances at $E_{^3He} = 1.1$, 1.4 and 2.2 MeV. They determined the possible spin-parity assignments for the corresponding ^{10}B states.

The 1.1 MeV resonance studied here has been seen previously only in the ^{7}Li (^{3}He, γ) ^{10}B and not in the ^{7}Li (^{3}He, α) ^{6}Li reaction, indicating $J^\pi = (1^+)$, 2^-, 3^+ as possible choices. We used the ^{7}Li (^{3}He, p) ^{9}Be and ^{7}Li (^{3}He, d) ^{8}Be reactions to obtain additional information.

2. Experimental procedure and results

The ^{3}He-beam of the 1.5 MeV Cockcroft-Walton accelerator of the »Boris Kidrič« Institute was analysed by an electrostatic analyser, defining the beam energy to ± 3 keV. The ^{3}He current at the target, placed at the centre of the scattering chamber, was typically about 0.5 μA. The target was 50 μg/cm^2 thick LiF evaporated on the nickel backing. A 2 mm thick silicon counter was used to detect protons up to $E_p = 14$ MeV. Elastically scattered ^{3}He ions were eliminated by a 1.8 mg/cm^2 Al foil placed in front of the detector. The pulses from the counter were fed to a low noise preamplifier and amplifier (ORTEC) and then to a 256-channel pulse-height analyser (TMC). The energy resolution obtained in the experiment for the p_0 group was 70 keV[3].

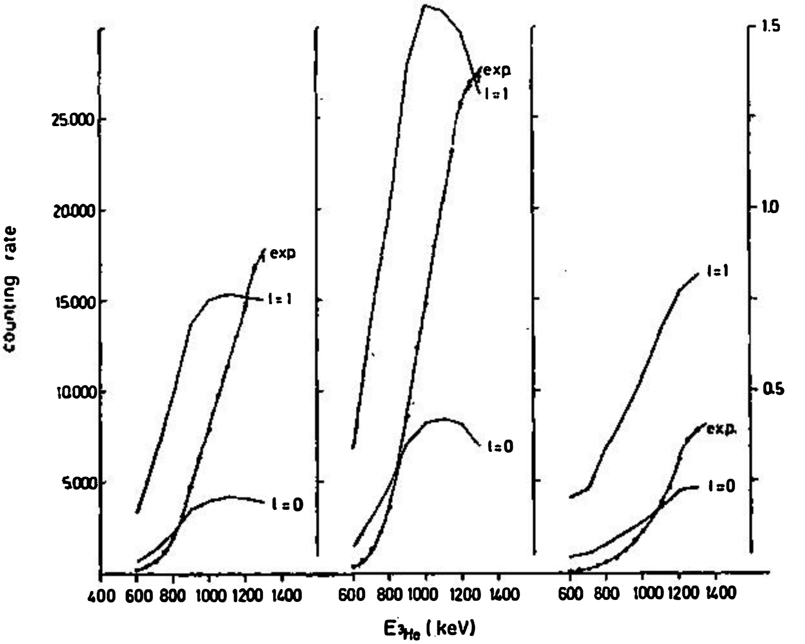

Fig. 1. 110° excitation functions for the ^{7}Li(^{3}He,p)^{9}Be ground state and second excited state reactions, and for ^{7}Li(^{3}He,d)^{8}Be ground state reaction.

The excitation functions, at $\theta_{lab} = 110°$, for the p_0, p_2 and d_0 groups, measured in steps of 50 keV for 600—1250 keV ^{3}He energy are shown in Fig. 1. The angular distributions for the p_0, p_2, p_3 and d_0 groups were measured at 900 keV and 1100 keV, from 0°—150° in steps of 10°. In Fig. 2 these angular distributions, which were mutually normalized at 110° using the excitation functions, are shown. Typical statistical errors are indicated on each curve. The angular distributions were fitted in terms of Legendre polynomials — the coefficients are given in Table 1.

3. *Discussion*

Since the Coulomb barrier strongly dominates the behaviour of excitation curves at low energy, we have computed the quantity:

$$A = \frac{N_{\mathrm{exp}}}{4\frac{k_{\mathrm{out}}}{k_{\mathrm{in}}} P_{l_{\mathrm{in}}} P_{l_{\mathrm{out}}}},$$

where N_{exp} is the c.m. yield taken from our excitation curves, k_{in} belongs to ^{3}He and k_{out} to p_0, p_2 or d_0, while $P_{l_{\mathrm{in}}}$ and $P_{l_{\mathrm{out}}}$ are Coulomb barrier penetration factors for incoming and outgoing channels. The quantity A computed for p_0, p_2 and d_0 in exit channels is given in Fig. 1.

Table 1.

group	$E_{^3\mathrm{He}}$ (keV)	A_0	A_1	A_2	A_3
p_0	900 1100	1.000 1.000	−0.268 −0.310	−0.152 −0.160	−0.006 −0.004
p_2	900 1100	1.000 1.000	−0.274 −0.125	0.076 0.099	0.072 0.003
p_3	900 1100	1.000 1.000	−0.185 −0.255	0.069 0.078	−0.013 −0.046
d_0	900 1100	1.000 1.000	0.226 0.284	−0.088 0.070	−0.090 −0.057

Table 1. Coefficients of the Legendre polynomials from the leas-squares fit of the data at 0.9 MeV and 1.1 MeV.

The existence of the 1.1 MeV resonance is clearly seen from the p_2 data and less strongly from the p_0 data. In order to account for such behaviour it is necessary to take into consideration both 1.1 MeV and 1.5 MeV resonances. With $\Gamma(1.5) \cong 650$ keV[1, 2], we concluded that $100 < \Gamma(1.1) < 400$ keV. Taking into account the calculation of the limiting values of Γ for different incoming l which were given by Paul et al.[1, 2], we conclude from $100 < \Gamma$ $(1.1) < 400$ keV that the 1.1 MeV resonance is made with $l = 0$ in the incoming channel leaving the 1^- and 2^- assignments as only possible choices for the corresponding level. However, since the p_2 group (which is the strongest proton group) could corespond to 2^- and 3^- assignments in its exit $l = 0$ channel, we conclude that the spin and parity of 1.1 MeV resonance is 2^-.

From Fig. 2 it is seen that the angular distributions for the p_0, p_2 and p_3 groups show the forward-backward asymmetry, which is increasing with energy. This seems to be a rather strong indication of the interference effects coming from the presence of two wide resonances at 1.1 MeV and 1.5 MeV (with the most probable opposite parities. Since the parity of the 1.1 MeV resonance is concluded above to be odd, it is very likely that 1.5 MeV resonance has even parity and since Paul et al. stated as the most probable

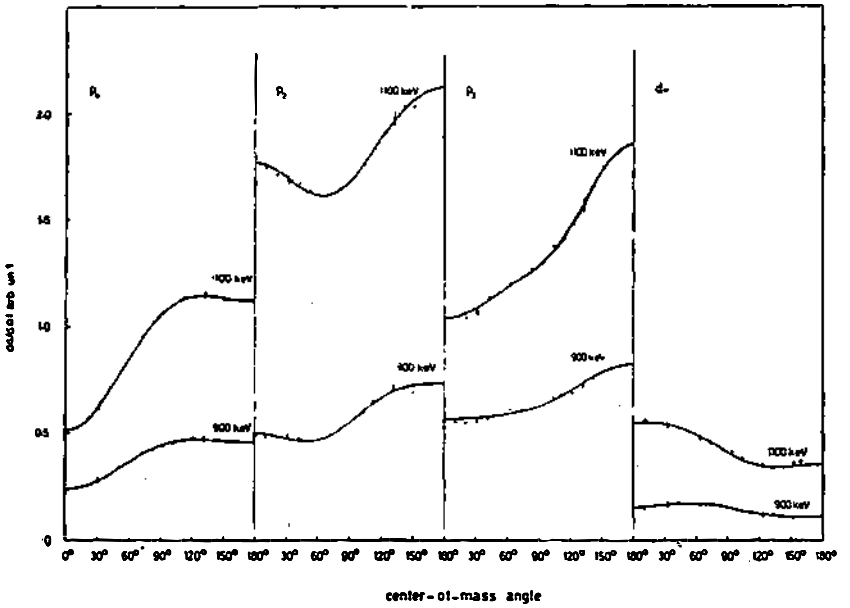

Fig. 2. Angular distributions of the proton groups, p_0, p_2 and p_3, from the reaction ^{7}Li(^{3}He, p)^{9}Be and of the deuteron group d_0 from the reaction ^{7}Li(^{3}He, d)^{8}Be for 0.9 and 1.1 MeV He energy. The solid line is the least-squares fit of the experimental points to the Legendre polynomials.

choices of spin-parity assignments of the 1.5 MeV resonances 2^+ or 1^-, our preceding conclusion on its even parity most probably leads to 2^+.

As it is seen from Fig. 1 any resonant behaviour is absent from d_0 data. The fact that 1.1 MeV resonance is not seen from both our d_0 data and the data of Paul et al.$^{2)}$, who studied alpha particles in exit channels, strongly favours the $T = 1$ character of this resonance. At the same time this indicates that even at such low energy the reaction ^{7}Li (^{3}He, d_0) ^{8}Be proceeds via direct process in which a proton stripped from ^{3}He might be captured by ^{7}Li in a *p*-state.

References

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REAKCIJA ^{7}Li + ^{3}He NA NISKIM ENERGIJAMA ^{3}He

D. M. STANOJEVIĆ, M. R. ALEKSIĆ, B. Z. STEPANČIĆ i R. B. POPIĆ

Institut za nuklearne nauke »Boris Kidrič«, Beograd

Sadržaj

Reakcije ^{7}Li (^{3}He, p) ^{9}Be i ^{7}Li (^{3}He, d) ^{8}Be ispitivane su radi dobijanja informacija o nivou na $E_x = 18.6$ MeV složenog jezgra ^{10}B. Izmerene su ekscitacione funkcije za p_0, p_2 i d_0 grupu, na $\theta = 110°$, u opsegu upadnih energija ^{3}He od 0.6—1.3 MeV, kao i ugaone raspodele za p_0, p_2, p_3 i d_0 grupu na 0.9 i 1.1 MeV. Efekti Coulombove barijere odstranjeni su kod ekscitacionih funkcija računanjem veličine A (formula 1) za $l = 0$ i 1 i u ulaznom i u izlaznom kanalu reakcije. Ova analiza ukazala je na egzistenciju rezonance na 1.1 MeV ($E_x = 18.6$ MeV) sa karakteristikama: $\Gamma = 100$—400 keV, $J^{\pi} = 2^-$ i $T = 1$. Analiza ugaonih raspodela izvršena je Legendreovim polinomom metodom najmanjih kvadrata. Kompleksnost ugaonih raspodela ukazuje na uticaj bliske rezonance na 1.4 MeV, verovatna karakteristika ovog stanja je 2^+. Analiza ekscitacione funkcije d_0 grupe iz reakcije ^{7}Li (^{3}He, d) ^{8}Be nije ukazala na egzistenciju rezonance na 1.1 MeV što sugerira da se ova reakcija odigrava najvećim delom preko direktnog mehanizma.