Energy and Angular Distribution of Alpha Particles in the $^{14}N(n, \alpha)^{11}B$ Reaction at 14.1 MeV

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The $^{14}N(n, \alpha)^{11}B$ reaction leading to the first five states of ^{11}B has been studied by using a cloud chamber at 14.1 MeV neutron energy. The angular distributions of a-particles present the evidence for the belief that the reation proceeds by the direct reaction mechanism. The theoretical fits to the angular distributions have been discussed in terms of heavy-particle stripping and knock-on processes.

1. INTRODUCTION

IN recent studies of (n, a) reactions at 14 MeV in the region of light nuclei ($A \leq 20$), angular distribution investigations have shown the existence of direct and exchange processes. Considerable efforts have been directed mainly to gain a better understanding of reaction mechanisms[1-10]. However, there is still a lack of sufficient experimental data for giving information on the mechanisms involved.

For the $^{14}N(n, \alpha)^{11}B$ reaction, the energy spectrum of a-particles at 14 MeV neutron energy was studied by Lillie[11], but no angular distribution has been investigated, yet. With a view of obtaining some informations of the nature, it was decided to study the $^{14}N(n, \alpha)^{11}B$ reaction.

2. EXPERIMENTAL METHOD

An expansion cloud chamber of 40 cm in diameter and 20 cm in height was employed to measure the energy spectrum and angular distributions of a-particles.

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It was filled with nitrogen gas mixed with 5% hellium gas to a pressure of one atmosphere and condensation was assured by water vapour. The admixture of the hellium gas was to aim to assure the clear tracks of a-particles. The whole experimental set-up was the same as that used in our previous report[8]. The subtraction of the $^{16}O(n,\alpha)^{13}C$ contribution due to the presence of water vapour in the chamber was done based on our previous experimental data. The number of tracks used was about 6300.

3. RESULTS AND DISCUSSION

The energy spectrum of the emitted a-particles with 0.1 MeV interval is shown in fig. 1. The peak corresponding to 6.76 and 6.81 MeV states of ^{11}B was not successfully separated.

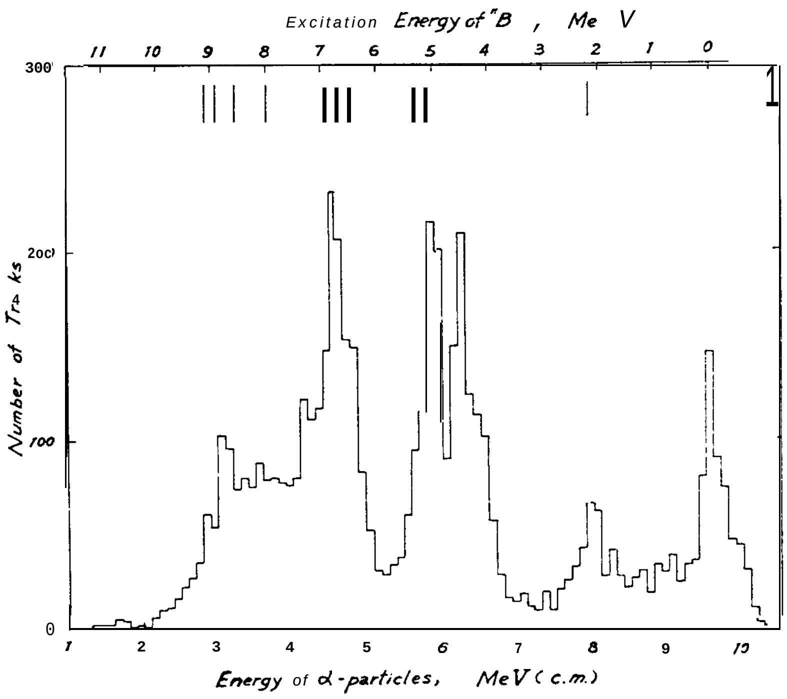

Fig. 1. Alpha-particle spectrum from the $^{14}N(n,\alpha)^{11}B$ reaction at 14.1 MeV

The angular distributions of a-particle groups leading to the ground and the first four excited states of ^{11}B are shown in fig. 2, 3, 4, 5 and 6. From the general appearance of these distributions, it is evident that the heavy-particle stripping process plays an important role in the $^{14}N(n,\alpha)^{11}B$ reaction, which implies the $(^{10}B+\alpha)$ structure of ^{14}N. Therefore, we consider that the knock-on rather than pick-up process may be operative at forward angles.

The plane wave Born approximation for the knock-on process gives the expression for the differential cross section as

$$\frac{d\sigma}{d\Omega} \propto |j_l(QR)|^2.$$

For the heavy-particle stripping process involving the exchange of the core ^{10}B between the systems (^{10}B + a) and (^{10}B $+n$), the differential cross section is given as[6,12,13]

$$\frac{d\sigma}{d\Omega} \propto |j_l(QR) j_l'(Q'R')|^2,$$

where l is the orbital angular momentum of the captured neutron in the residual nucleus and l' is the relative orbital angular momentum at which the u-particle leaves the target nucleus; R and R' and the core-neutron and core-a interaction radii; Q and Q' are the momentum transfers of neutron and a-particle, respectively.

From the study of the ^{10}B$(d,p)^{11}$B reaction[14,15], it is understood that the ^{10}B nucleus captures a neutron with $l=1$ in order to form the first five states of ^{10}B. This also conforms to the shell model theory which describes that ^{11}B will have the properties of the polyad p^7. In the ^{14}N$(n$, a) ^{11}B reaction, it is also reasonable to consider that the neutron must be captured in P-state, which gives the values of $l=1$ and $l'=2$. But then the conservation of angular momentum does not permit formulation of the first excited state of ^{11}B$(J^{\pi}=½)$ by simple addition of a P-neutron to the ground state of ^{10}B(3^-). For resolving this difficulty, we assume that u-particle leaves the target nucleus with ^{10}B core left in the excitation (1^+), which in turn captures a P-neutron to form the ½ state of ^{11}B. This picture gives the valuls of $l=1$ and $l'=0$. In fig. 3, we show the observation compared with the calculated curve, using $l=1$ and $l'=0$, for the first excited state of ^{11}B. For the ground and the other excited states, the theoretical fits were obtained by using $l=1$ and $l'=2$ (figs. 2, 4, 5 and 6).

Comparison of the present experimental data with the calcualted curve shows that actually the angular distributions in the backward region can be attributed to the heavy-particle stripping process, while the forward peaks to the knock-on process. These mechanisms have already been invoked to account for the similar angular distributions in the reactions of ^{9}Be$(n,\alpha)^6$He[1], ^{12}C$((n,\alpha)^9$Be[2-4], ^{16}O$(n,\alpha)^{13}$C[4-9], and ^{20}Ne$(n$, a) ^{17}O[10]. Our present results may give further evidence for these mechanisms in light nuclei.

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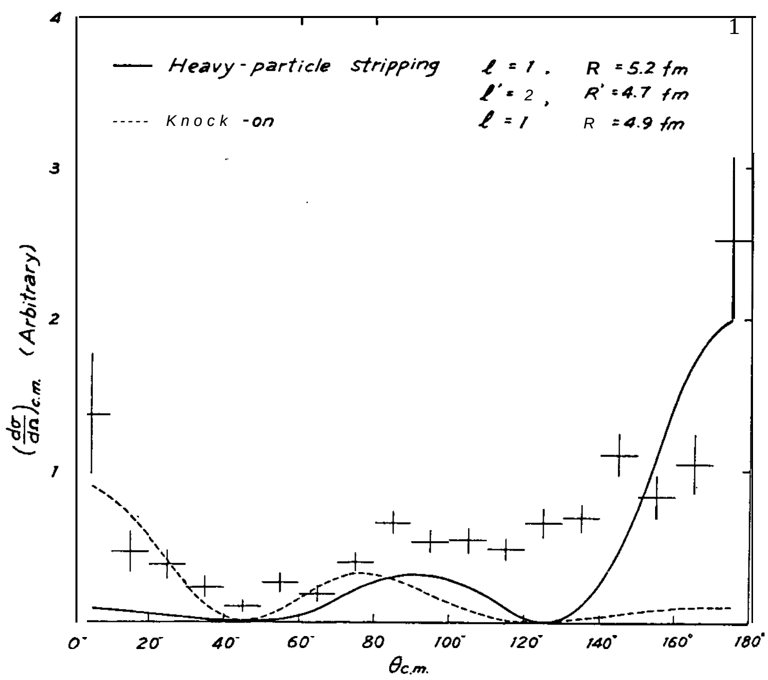

Fig. 2. Angular distribution of a particles leading to the ground state of ^{11}B

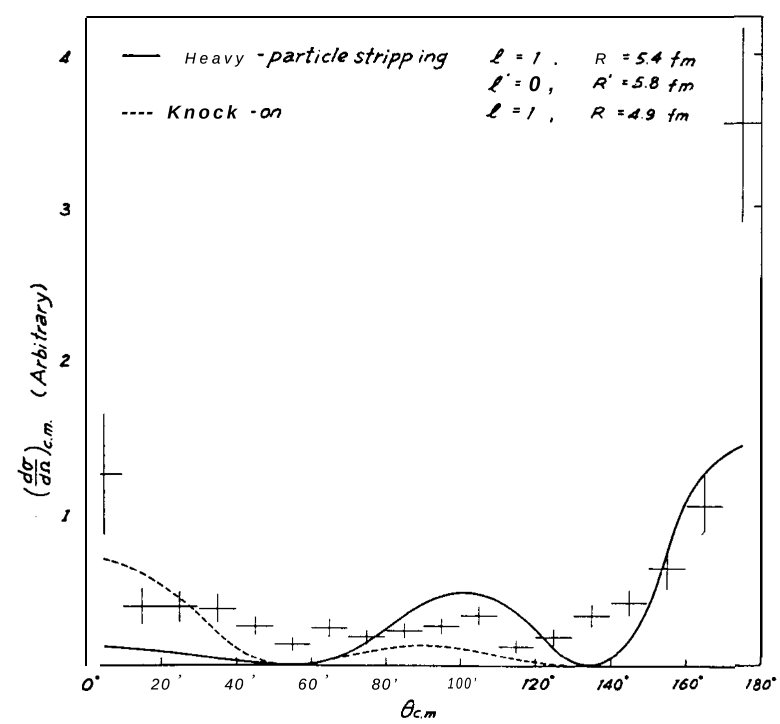

Fig. 3. Angular distribution of a particles leading to the 2.14 MeV state of ^{11}B

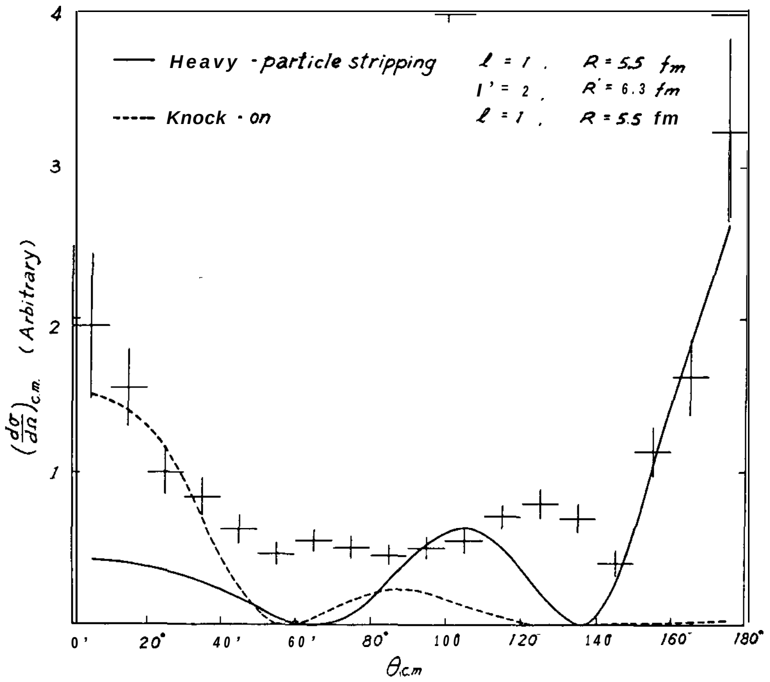

Fig. 4. Angular distribution of a-particles leading to the 4.46 MeV state of ^{11}B

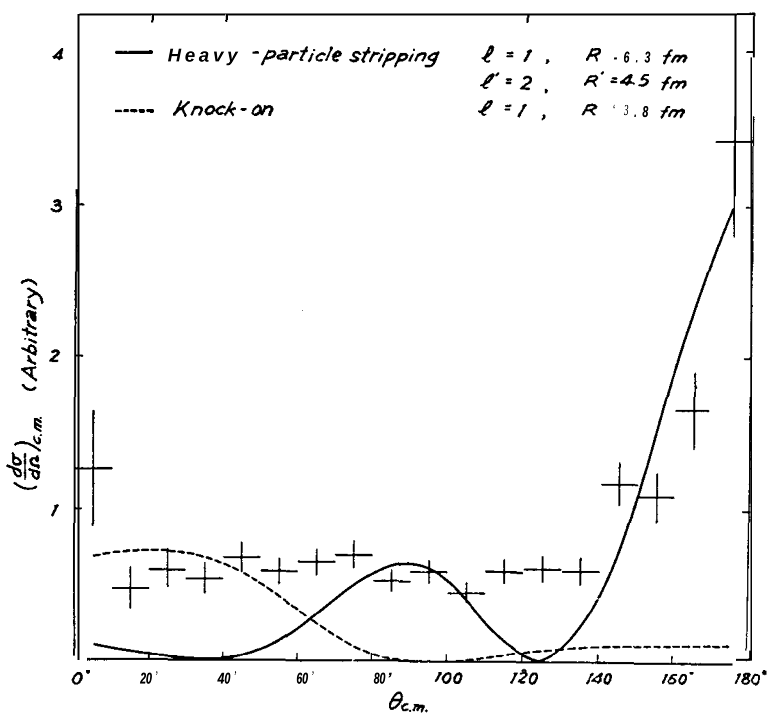

Fig.5. Angular distribution of a-particles leading to the 5.03 MeV state of ^{11}B

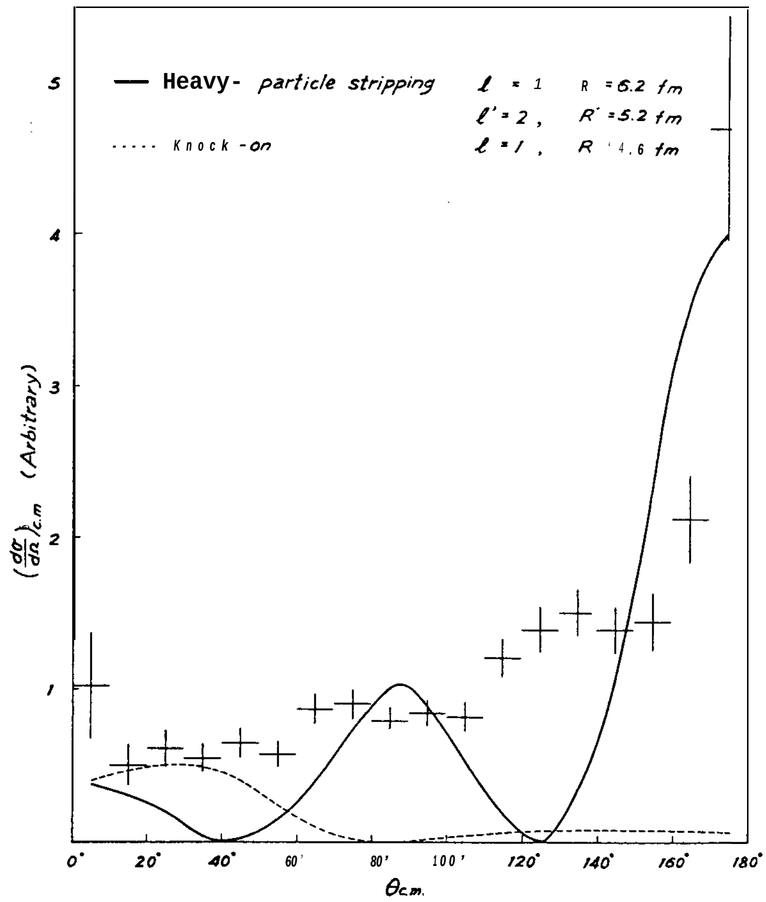

Fig. 6. Angular distribution of a-particles leading to the 6.76 MeV and 6.81 MeV states of ^{11}B

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