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$^9Be + n \rightarrow {}^4He + {}^6He$ REACTIONS INDUCED BY FAST NEUTRONS[1]

WŁODZIMIERZ SMOLEC,* STANISŁAW BURZYŃSKI,*
KRZYSZTOF RUSEK,* IRENA M. TURKIEWICZ,* JAN TURKIEWICZ,*
PAWEŁ ŹUPRAŃSKI,* Warsaw

An experiment has been performed on the $^9Be(n, \alpha)\,{}^6He$ reaction induced by neutrons in the energy range 12—18 MeV. Differential cross sections have been measured at 12.2, 14.1 and 18.0 MeV incident energies. Excitation functions for the emission of the reaction products in the forward direction were also measured.

Due to know technical reasons the experimental studies of the angular distributions in fast neutron induced (n, α) reactions are limited mainly to energies close to 14 MeV. Consequently the conclusions about the reaction mechanism are often based on measurements made at only one energy and may be sometimes misleading. The dependence of the angular distribution features on the energy provides an additional important information about the reaction mechanism. Thus the investigations in the wider energy range may add to our understanding of the (n, α) reactions. Here we report the results of the $^9Be\,(n, \alpha)\,{}^6He$ reaction study in the energy range from 12 to 18 MeV. The angular distribution of α particles leading to the ground state of ^6He measured at 14.1 MeV [2] was strongly backward peaked, which was interpreted as a dominance of the heavy particle stripping mechanism in this reaction. As the shape of the heavy particle stripping angular distribution should not exhibit a large energy dependence we made an attempt to check if it really held in this case.

The experimental set-up was described in detail elsewhere [1]. As a neutron source the $T(d, n)\,{}^4He$ reaction induced by 2 MeV deuterons was used. A counter telescope consisting of proportional and semiconductor counters was used. During experimental runs $(\Delta E, E)$ events were stored on a magnetic tape and simultaneously fed into a minicomputer (constructed at the Institute of Nuclear Research, Swierk, in the Camac system) for processing the data on line. As a result a particle identification was effected and pulse-height distributions for different particles were extracted. Fig. 1 shows an example of one-dimensional spectra of ^4He and ^6He taken at the angle of 0° and the neutron energy of 18 MeV. In the α-particle spectra we can distinguish the transitions to the ground (α_0) and the first excited (α_1) states of ^6He at 1.79 MeV. Higher states of ^6He reported by some authors [4, 5] lie in the region of spectra where the products of the three- and four-body break-up and the carbon contamination in the target are presented and we will not discuss them.

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* Institute of Nuclear Research, Hoza 69, WARSAW, Poland.

In Figs. 2 and 3 the angular distributions of α-particles leading to the ground and the first excited states of ^6He are presented. In the case of the α_1 distribution the angular range covered by the experiments is limited to 0°—90° because of the large background appearing at higher angles. The α_0 distribution was obtained in the 0°—180° range owing to the possibility for measuring the residual ^6He recoils in the forward direction.

Each angular distribution presented in Figs. 2 and 3 is a result of three independent series of measurements. We estimate the error in the absolute cross-section scale at about 30 %. The determination of the neutron flux constitutes the main uncertainty. The angular spreads due to the extended geometry were calculated by the Monte-Carlo program and ranged from ±3° to ±5° in the laboratory system.

Fig. 4 shows the energy dependence of α_0, α_1 and the ^6He yields when the telescope was set at 0° with respect to the direction of the incident neutrons.

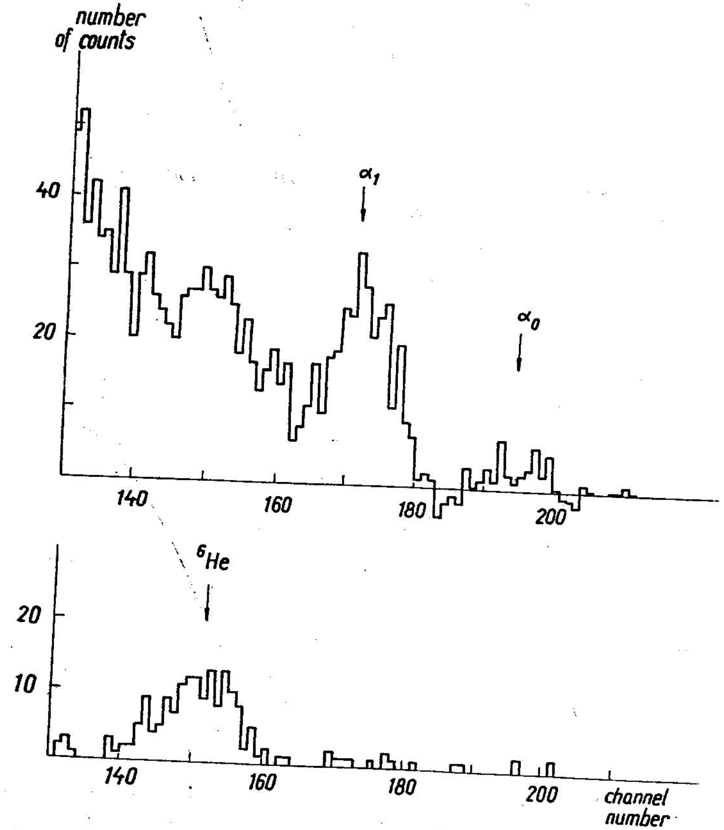

Fig. 1. An example of the one-dimensional spectra selected from the events obtained during a 20 hour measurement under the following conditions: neutron energy — 18 MeV, telescope position — 0°, target — 1.6 mg/cm² of Be on the thick graphite backing. The background from graphite, measured under the same conditions, has been subtracted.

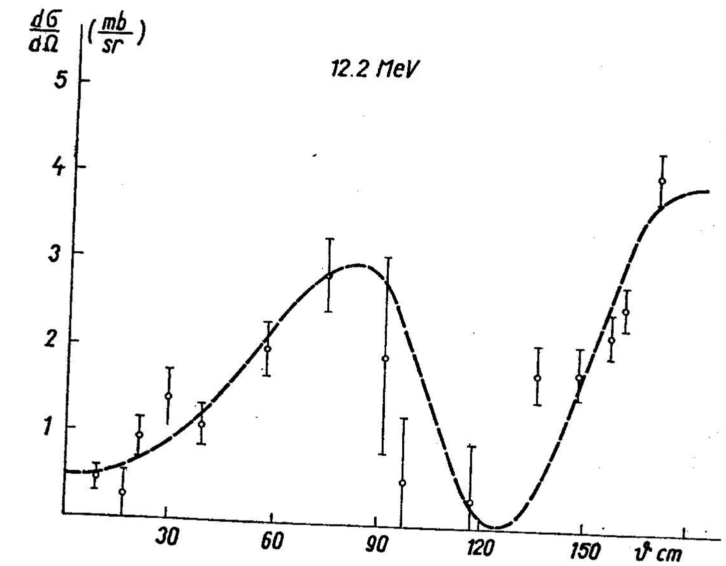

Fig. 2a

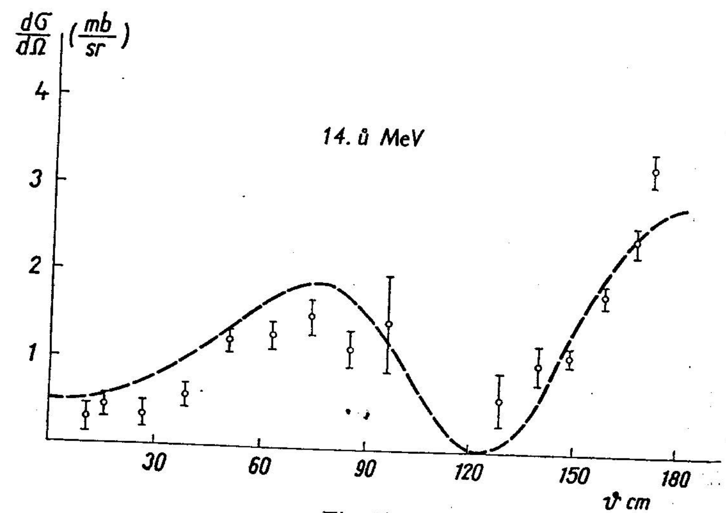

Fig. 2b

Fig. 2. The angular distributions of α-particles corresponding to the ground state of ^{6}He obtained at the neutron energies of: a — 12.2 MeV, b — 14.1 MeV, c — 18 MeV. The indicated errors are statistical only. Theoretical curves were calculated with the following out-off radii: 1) of the neutron-core interaction — 0.1 fm for all energies, 2) of the alpha-core interaction 5.5, 5.0, 4.3 fm for the energies of 12.2, 14.1, 18 MeV, respectively.

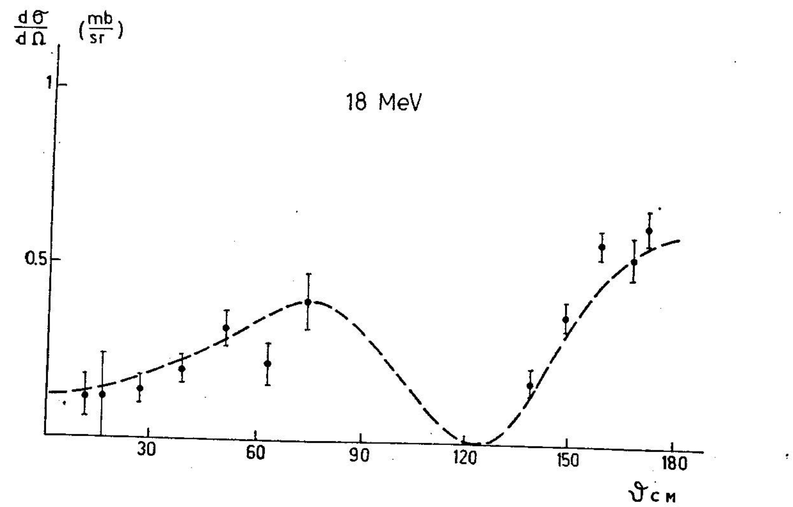

Fig. 2c

From Figs. 2 and 3 one can see that the angular distributions taken at three different energies show no striking difference, which can corroborate the earlier [2] suggestion about a direct process govering this reaction.

An attempt has been made to analyse the α_0 angular distributions in terms of the theory of direct nuclear reactions given by Edwards [3]. The contribution from the

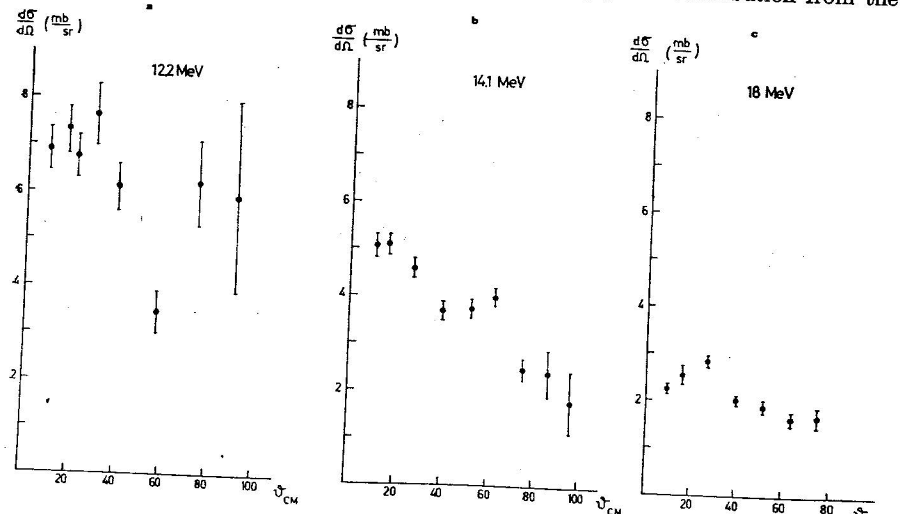

Fig. 3. The angular distributions of α-particles corresponding to the first excited state of the obtained at neutron energies of: a — 12,2 MeV, b — 14.1 MeV, c — 18 MeV. The indicated errors are statistical only.

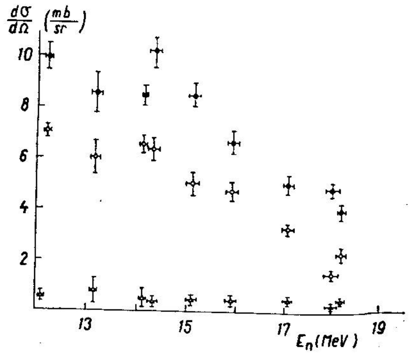

Fig. 4. The excitation functions of the ○ — ^{9}Be(n, α_0) ^{6}He, ● — ^{9}Be(n, α_1)^{6}He, Δ — ^{9}Be(n, ^{6}He) transitions obtained with the telescope set at the angle of 0° in the incident neutron direction. The indicated errors are statistical only.

two modes corresponding to the pick-up and the heavy particle stripping were added coherently with adjustable multiplication constants.

A satisfactory fit was obtained with a small relative contribution of the pick-up mechanism. The curves drawn in Fig. 2 are obtained when only a heavy particle stripping term was present.

The cluster structure of ^{9}Be was assumed as ^{4}He + ^{5}He in the 3s state. The goodness of fit depends as usual on the choice of cut-off radii. The radii obtained for our fits are quite reasonable in view of recent considerations on the structure of the light nucleus [6].

It is worthwhile to note that the angular distributions for the ^{9}Be(n, α) ^{6}He reaction measured at three different energies are all fairly well described by the heavy particle mechanism [3].

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