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A STUDY OF THE $^{12}C(t, n)^{14}N$ REACTION AT 1.1–1.7 MeV

BY K. MAŁUSZYŃSKA AND M. PRZYTUŁA

Department of Experimental Physics, Łódź University*

AND I. V. SIZOV

Joint Institute for Nuclear Research, Dubna, USSR

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Angular distributions of three neutron groups from the ^{12}C (t, n) ^{14}N reactions have been measured at 1.12, 1.26, 1.375 and 1.68 MeV using the nuclear-emulsion method. A strong dependence of the shape of the angular distribution for the n_0 group on the triton energy was observed. The angular distributions of the n_1 group are very similar to those of the $^{12}C(t, p_0)$ reaction. A large maximum at backwards angles was found for the n_2 group at 1.68 MeV.

1. Introduction

A number of papers concerning nuclear reactions induced by particles with mass number $A = 3$ has been published in the last few years. The purpose of some of them was to investigate the nuclear-reaction mechanism.

In some cases the change of character of the angular distributions in the energy range 1 –6 MeV suggests distinct change in the reaction mechanism [1–5]. Only a few data concerning the (t, n) reaction have been published, because of difficulties of neutron spectroscopy and the particularly troublesome work with tritium gas. The angular distributions for unresolved neutron groups and corresponding excitation functions have been published [6–11]. The neutron spectra have also been published [12].

This paper concerns the ^{12}C (t, n) ^{14}N reaction at triton energies $E_t = 1.12$, 1.26, 1.375 and 1.68 MeV. The neutron spectra and angular distributions corresponding to the ground state and the two first excited levels of the residual nucleus were investigated. Our measurements complete to some extent previous investigations of (t, p_0), (t, α_0) and (t, α_1) reaction channels performed in JINR, Dubna [13]; they are a continuation of the work of Ref. [14].

* Address: Instytut Fizyki Uniwersytetu Łódzkiego, Łódź, Narutowicza 68, Polska.

The differential excitation function of the $^{12}C(t, n)\,^{14}N$ reaction at 0° for unresolved neutron groups in the triton energy range 0.35–2.4 MeV and the angular distributions have been presented [6]. A number of maxima on the excitation function was interpreted as the resonances connected with the compound nucleus ^{15}N. The angular distributions of neutrons are symmetric with respect to 90° below 1.5 MeV; they become asymmetric above 1.5 MeV with a maximum at backwards angles. It seemed interesting to study whether the symmetry of the angular distributions also appears for separate neutron groups at lower energies and to find groups responsible for asymmetry at triton energies above 1.5 MeV.

2. *Experimental procedure*

The neutron spectra were measured using nuclear emulsions NIKFI Ya-2, with dimensions 20 mm × 40 mm and 200–250 μm thickness. The emulsions were enveloped in black paper and placed in an aluminium frame fixed at a distance 75 mm from the carbon target on an aluminium ring. The average angle between the incident neutron direction and the emulsion plane was 3°20′. The carbon target was made by depositing soot from burning benzine on a thick stainless steel backing. The tritons were accelerated in the 2 MeV van

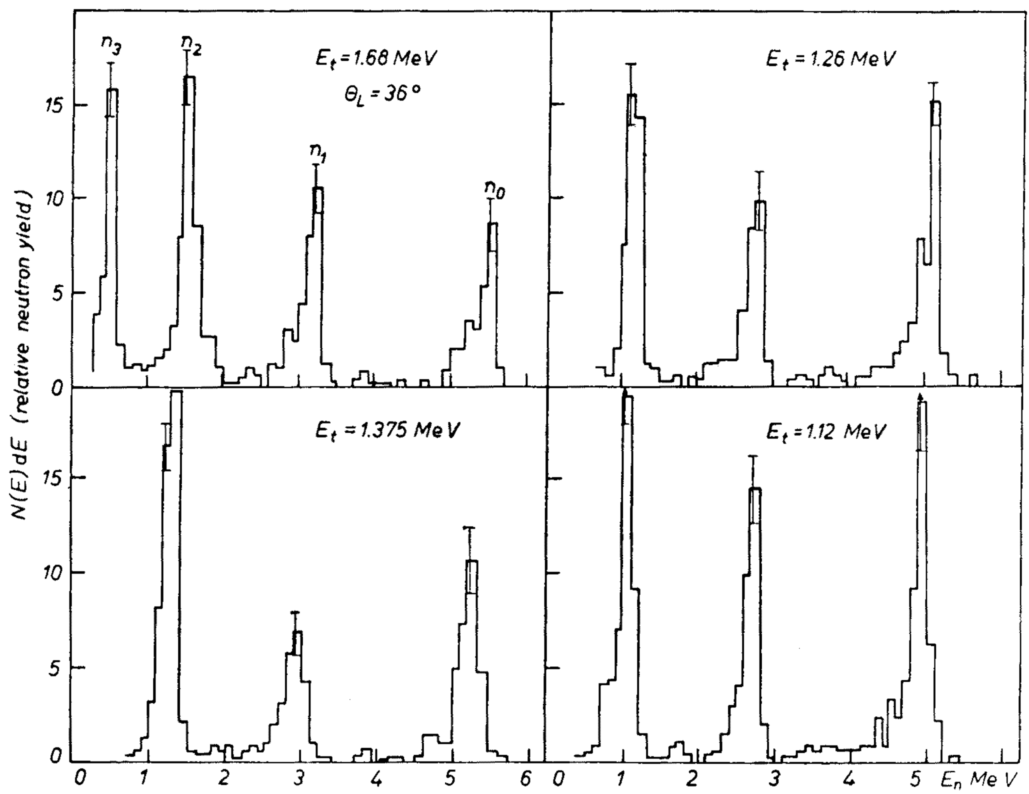

Fig. 1. Neutron spectra at 36° for different triton energies

de Graaff generator of JINR, Dubna with magnetic deflection of the beam. The target thickness was estimated at 20–40 keV.

The nuclear emulsions were scanned at the Department of Experimental Physics, Łódź University. The proton recoil tracks were measured in a pyramid with the angle 10° between the pyramid faces and incident neutron direction. The magnification was 900. The measurements were made for angles from 3° to 162° in the lab system. About 34 000 tracks were measured.

3. *Results*

The neutron spectra were measured for ten angles in intervals of about 18°. The spectra for 36° at different triton energies are shown in Fig. 1. Three separate neutron groups n_0, n_1 and n_2 corresponding to the ground state and the first two excited levels of the ^{14}N nucleus

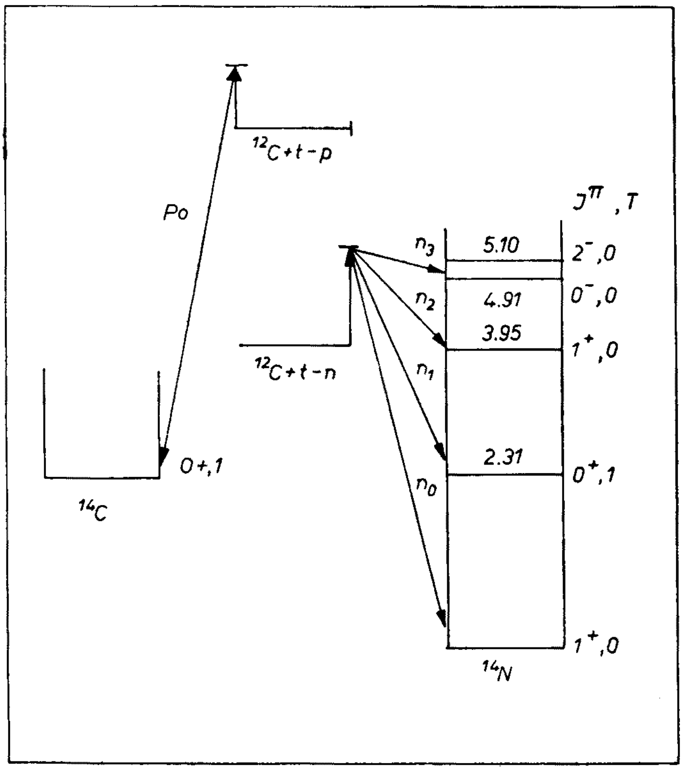

Fig. 2. Level scheme of ^{14}N

(Fig. 2) appear distinctly in all spectra. The background occurring between the neutron groups is attributed mostly to the ^{13}C (t, n) ^{15}N reaction ($Q = 9.896$ MeV). The abundance of ^{13}C in the target is about 1.1%. The neutron groups may be emitted from this reaction in the investigated energy range. Nevertheless, the contribution of these neutrons lies within the error limits and may be neglected.

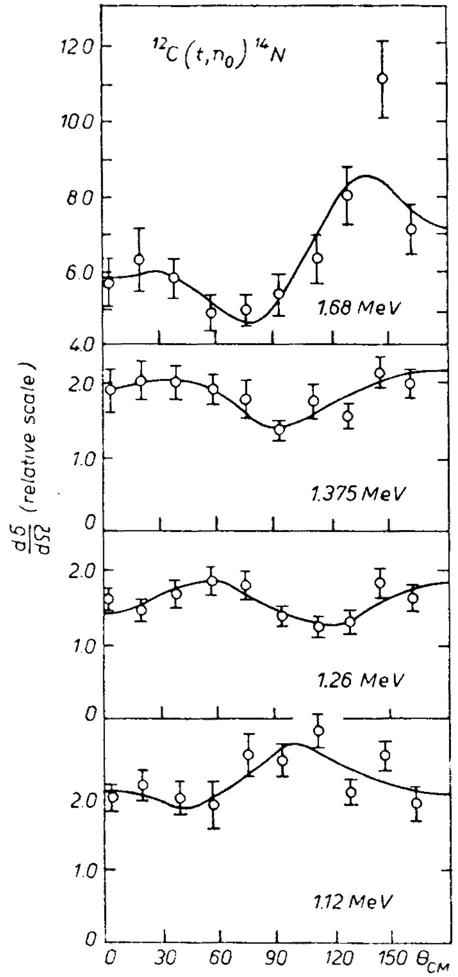

Fig. 3

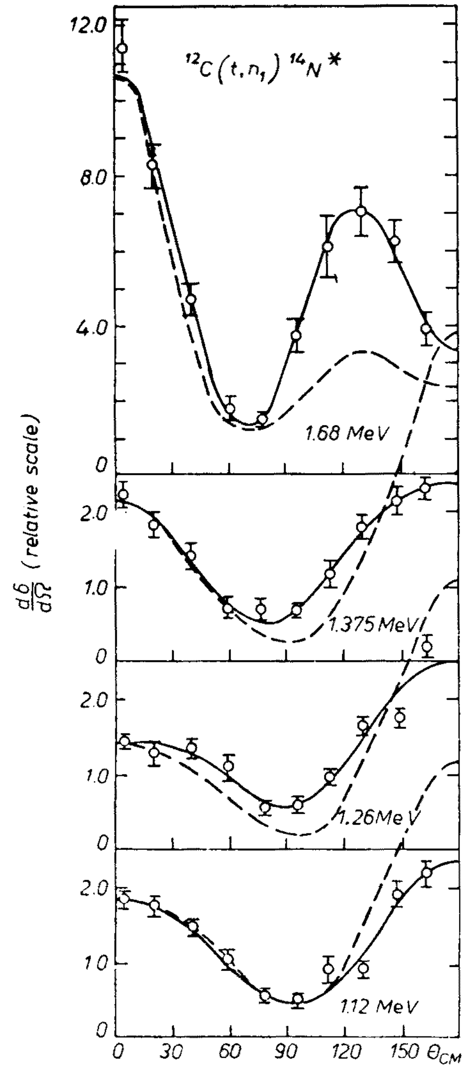

Fig. 4

Fig. 3. Angular distributions of neutrons for n_0 group at 1.68, 1.375, 1.26, and 1.12 MeV triton energy
Fig. 4. Angular distributions of neutrons for n_1 group at 1.68, 1.375, 1.26 and 1.12 MeV triton energies

At the triton energy 1.68 MeV, the approximate contribution of the neutron group n_3 from the small angles corresponding to the 4.91 MeV excited level of ^{14}N with an admixture of neutrons corresponding to the 5.10 MeV level was estimated.

On account of the difficulties connected with the measurement to the short tracks, all the results referring to the n_3 group and those for the backwards angles of the n_2 group at the lowest energies are regarded as doubtful.

The measured angular distributions are shown in Figs 3–5. The solid lines are least-squares fits of sums of Legendre polynomials to the data. The fit includes five polynomials.

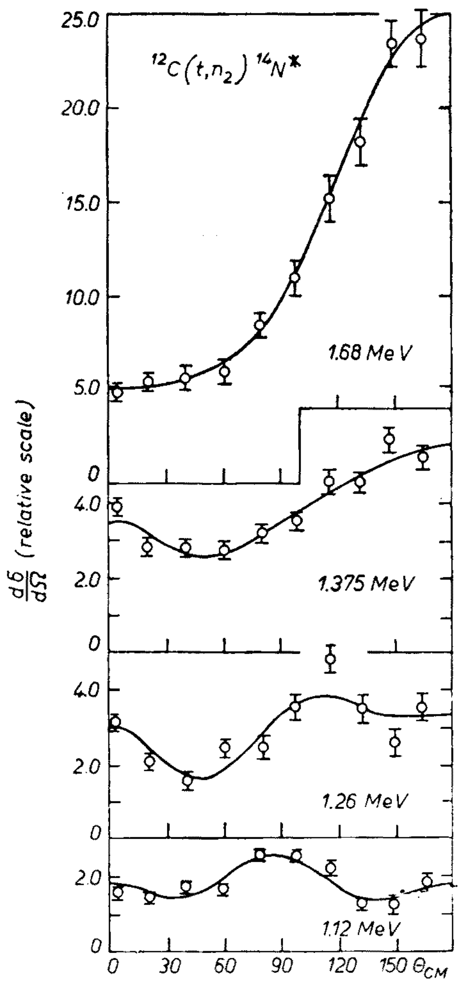

Fig. 5. Angular distributions of neutrons for n_2 group at 1.68, 1.375, 1.26 and 1.12 MeV triton energies

The shape of the angular distribution for the n_0 group changes quite rapidly with energy and may suggest the occurrence of a compound nucleus mechanism. Owing to the small number of experimental points, we are not able to determine the excitation function structure. However, the cross-section for the n_0 group obtained by integration of the angular distributions is greater at 1.12 MeV than at 1.26 MeV (Fig. 6); this may be connected with the resonance at 1.1 MeV observed in the $^{12}C(t, p_0)$ and $^{12}C(t, \alpha_2)$ reactions [13].

The similarity between the angular distributions of the n_1 group and protons from the $^{12}C(t, p_0)$ reaction [13] in the entire investigated energy range is noticeable. The angular distributions of protons are plotted in Fig. 4 as dashed lines. The n_1 and p_0 groups correspond to the analogous states of final nuclei which are the constituents the isobaric triad (Fig. 2).

An interesting feature of the n_2 angular distributions is the increase in the backwards angle maximum with increasing energy. At the triton energy of 1.68 MeV, the $\sigma(180°)/\sigma(0°)$

ratio reaches the value of 5. It seems however unjustifiable to conclude from this fact without any theoretical analysis that the heavy stripping contribution increases with energy.

The present results indicate the composite nuclear reaction mechanism at relatively low energies. The data presented are however too poor for detailed analysis and interpretation of the reaction mechanism. We are therefore continuing the study of (t, n) reactions on other light nuclei.

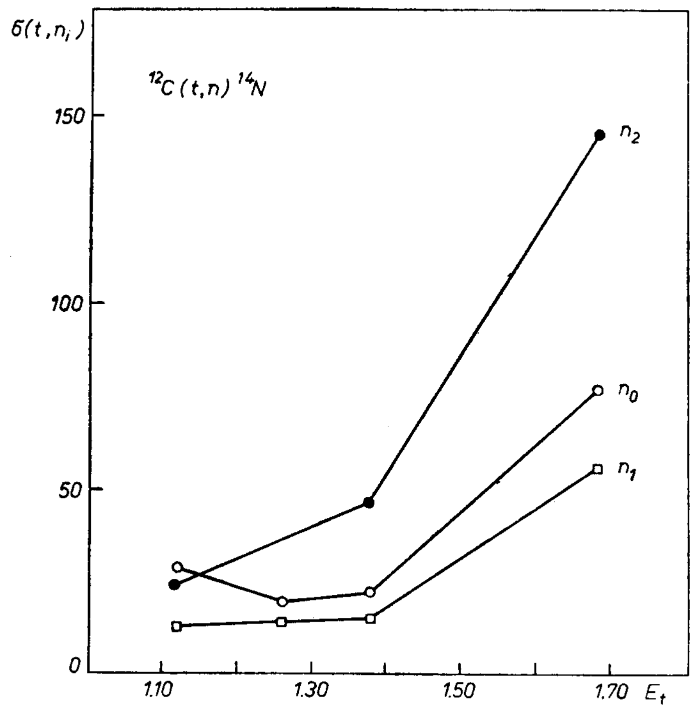

Fig. 6. Dependence of the cross-section for ^{12}C (t, n_0) ^{14}N, ^{12}C (t, n_1) 14N* and ^{12}C (t, n_2) $^{14}N^*$ on triton energy

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