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A STUDY OF THE ENERGY SPECTRUM OF ALPHA PARTICLES FROM THE $Tb^{159}/n.\alpha/Eu^{156}$ REACTION WITH 14.2 MeV NEUTRONS

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A STUDY OF THE ENERGY SPECTRUM OF ALPHA PARTICLES FROM THE Tb^{159} /n, α/ Eu^{156} REACTION WITH 14.2 MeV NEUTRONS

ROZKŁAD ENERGETYCZNY CZĄSTEK ALFA Z REAKCJI Tb^{159}/n, α /Eu^{156} PRZY ENERGII NEUTRONÓW 14,2 MeV

ЭНЕРГЕТИЧЕСКИЙ СПЕКТР α - ЧАСТИЦ ИЗ РЕАКЦИИ Tb^{159}/n, α /Eu^{156} ВЫЗВАННОЙ НЕЙТРОНАМИ 14,2 Мэв

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Abstract

The energy spectrum of α -particles from Tb^{159}/n, α/Eu^{156} reaction at 14.2 MeV has been studied using semiconductor detector technique. The characteristic feature of the observed energy spectrum is the existence of four separate maxima in the energy region 15 - 21 MeV. The positions of these maxima are explained assuming that there exists a large contribution of the knock-out process in the mechanism of the investigated reaction.

Streszczenie

Stosując technikę detektorów półprzewodnikowych zmierzono rozkład energetyczny cząstek alfa z reakcji Tb^{159} /n, α / Eu^{156} przy energii neutronów 14,2 MeV.

Charakterystyczną cechą obserwowanego widma cząstek α jest istnienie czterech oddzielnych maksimów w obszarze energii od 15 MeV do 21 MeV.

Istnienie tych maksimów można wytłumaczyć przez przyjęcie dużego wkładu procesu wybijania cząstek w mechaniźmie badanej reakcji.

Содержание

При помощи техники полупроводниковых детекторов измерялось энергетическое распределение α - частиц из реакции Tb^{159} /n, α /Eu^{156} при энергии нейтронов I4,2 Мэв.

В исследованном спектре наблюдалось четыре максимума, существование которых объясняется значительным вкладом процесса выбивания α - кластеров в механизме изучаемой реакции.

1. INTRODUCTION

During few recent years some progress may be observed in the accumulating of data concerning /n, α / reactions in the region of heavy nuclei.

Apart of the total cross-sections data obtained by the activation method [1] there exist some results on the energy spectra and angular distributions measurements for /n, α / reactions induced in heavy nuclei by fast neutrons [2], [3], [4], [5], [6], [7], [8], [9],

From the analysis of the total cross sections measurements Saetta-Menichella et al [10] and Facchini et al [11] concluded that the statistical model applied with success to the description of the /n, α / reactions for heavy nuclei.

This statement is in contradition with the results obtained by us for La^{139} /n, α / Cs^{136} reaction [7] and by Kulisić et al [8] for Pr^{141} /n, α /La^{138} reaction for neutron energies about 14 MeV. These results suggest the existence of direct effects in the investigated reactions. Marcazzan et al [6] have also found the presence of direct effects in Ta^{181} /n, α / Lu^{178} and Au^{197} /n, α / Ir^{194} reactions.

To solve the problem of the mechanism governing /n, α/ reactions in heavy nuclei it is necessary to compile more experimental data concerning particularly the energy and angular distributions of emitted α - particles.

The present work gives the results on the alpha-par-

ticle spectrum measurements for the reaction Tb^{159} /nα/ Eu^{156} with 14.2 MeV neutrons.

II. EXPERIMENTAL METHOD

The geometry of the experiment was the same as described in our earlier paper [7]. Experimental arrangement is shown in Fig. 1.

The Tb_2O_3 deposited on graphite was placed at a distance of 8 mm from the silicon detector. The mean thickness of the terbium oxide layer was about 5.2 mg/cm^2. Both the detector and the investigated target were housed in a vacuum chamber lined with aluminium. This ensured the reduction of the background due to /n,α / reactions produced in the walls of the chamber.

The detector used in this experiment was an n-type surface barrier silicon detector with the resistivity of about 2000 Ω cm. The barrier thickness determined by the bias applied to the detector, corresponded to a range of 26 MeV alpha particles.

The pulses from the detector were fed to a charge sensitive preamplifier followed by a linear amplifier, threshold amplifier and 128-channel analyser. The energy scale of the spectrometer was determined using alpha particles from ThC and ThC' and from reactions Si^{28} /n,α / Mg^{25} and Si^{29} /n,α / Mg^{26g} produced in detector by fast neutrons. During the experiment we continuously checked

the energy scale using alphas from Si^{29} /n, α / Mg^{26g} reactions. Neutrons of energy of about 14.2 MeV were obtained from H^3 /d, n/ He^4 reaction with deuterons accelerated up to 500 keV in a Van de Graaff accelerator. The possibility of detecting α - particles from terbium by means of a single detector is due to the negative Q-values for the /n, α / reactions on silicon isotopes and high positive Q-value /+5.85 MeV/ for Tb^{159} /n, α /Eu^{156} reaction.

The Coulomb barrier effects limit the energy of the investigated particles in the lower energy part of the spectrum. We observed the sharp drop of the number of alpha particles emitted with the energies lower than 16 MeV.

However, the energy region in which alpha particles were investigated was not free from background pulses, as it follows from Q-values consideration. The background pulses are due mainly to the pile up of the smaller pulses created in silicon. This background was measured by bombarding the silicon detector when the terbium oxide layer was removed. In order to get this background not too high it was necessary to use low neutron fluxes. This fact and the use of the thin terbium target caused the measurements to be relatively long. The total time of the measurements amounted to 180 hours.

III. RESULTS

The results of the α-particles spectrum measurements for Tb^{159} /n,α / Eu^{156} reaction are shown in Fig. 2. This spectrum was obtained for the forward angles /$0^{\circ} \pm 60^{\circ}$/. The corrections accounting the energy loss in the target layer were calculated unsing tables given by Williamson and Boujot [12].

The characteristic feature of the observed spectrum is the existence of four well pronounced peaks. In the earlier measurement [9] these peaks were not resolved becouse of the poorer statistics and probably worse energy resolution.

Our results were obtained during three series of measurements. Each of the series consisted of many runs in which alternate measurements of the effect and of the background were performed. It is worth note a good agreement between the data collected in the individual series.

The levels of Eu^{156} i.e. of the final nucleus to which investigated reaction goes are not known.

However at the excitations corresponding to the energies of the alpha particles observed in the experiment, there are probably very many levels. If direct interaction mechanism, with α - particles emitted mainly in knock-out process, dominates in Tb^{159} /n,α /Eu^{156} reaction it seems resonable to expect the single neutron levels to be strongly excited.

The results of the calculation of the single neutron level density in a deformed potential based on Nilson's work [13] are presented in Fig.3 in a diagramtic form. The arrows show the positions of the maxima observed in the experimental spectrum. The value of the deformation parameter δ for Eu^{156} was taken 0.3. This value is close to the deformation parameter values measured for neighbouring nuclei. The neutron ground state was according to [14] assumed to be the [5.2.1] . Nilsson's level for $\Omega = 3/2$.

As can be seen, the positions of the observed maxima agree with those appearing in the calculated level density. As the Nilsson schema gives the location of levels only semiquantitatively the agreement is rather good. Also, when performing this comparison one supposes that all single neutron levels are excited with equal probabilities. This is an approximation.

A similar enhancement of single particle excitations has been previously observed in /n,p/ and /d,p/ reactions [15], [16], [17]. The strong excitation of single neutron levels suggests that in the investigated reaction the knock-out alpha substructures from nuclear surface plays an important role. The pick-up mechanism of He^3 substructures would not lead to the strong excitation of single neutron levels.

To summarise, one may conclude that the results of present work show a large contribution of the direct interaction mechanism in the Tb^{159} /n,α/ Eu^{156} reaction with 14 MeV neutrons. The same conclusion has been drawn by Zagreb

Group [9]. As we have been able to obtain separate maxima in the alpha particle spectrum, we may conclude that the main contribution to the cross-section of the inveatigated reaction comes from the knock-out mechanism. This conclusion may stand for the validity of the assumption made in the interpretation of the results obtained for the $La^{139}/n,\alpha/Cs^{136}$ reaction [18] where the knock-out mechanism of alpha substructure from the nuclear surface was assumed to be dominant.

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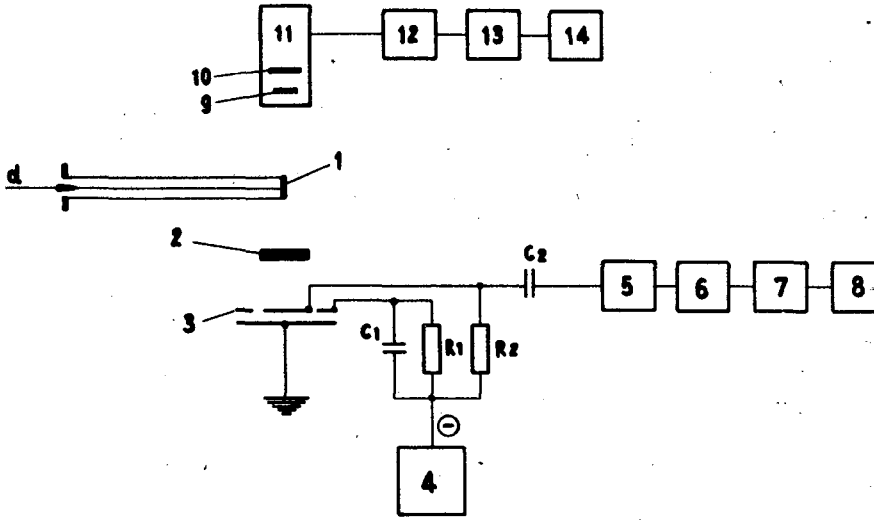

Fig. 1 Schematic diagram of the experimental arrangement

1. T-Ti target
2. Tb_2O_3 layer
3. silicon surface barrier detector
4. stabilized power unit
5. charge sensitive preamplifier
6. linear amplifier
7. threshold amplifier
8. multichannel analyzer
9. poliethylene foil
10. CsI/Tl/ scintilator
11. EMI 9530 photomultiplier
12. linear amplifier
13. discriminator
14. scaler

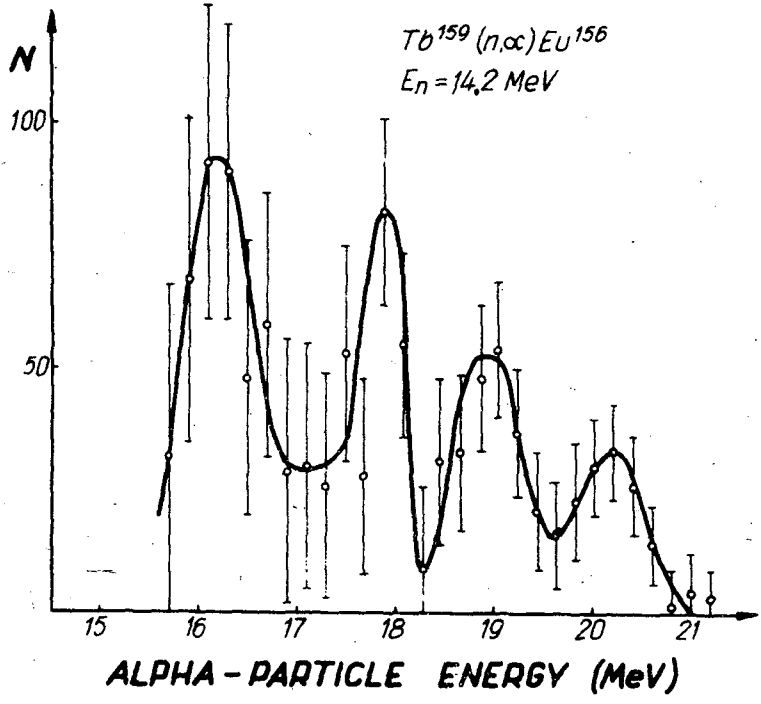

Fig. 2 Energy spectrum of α -particles /corrected for background/ from the reaction Tb^{159} /n, α / Eu^{156}

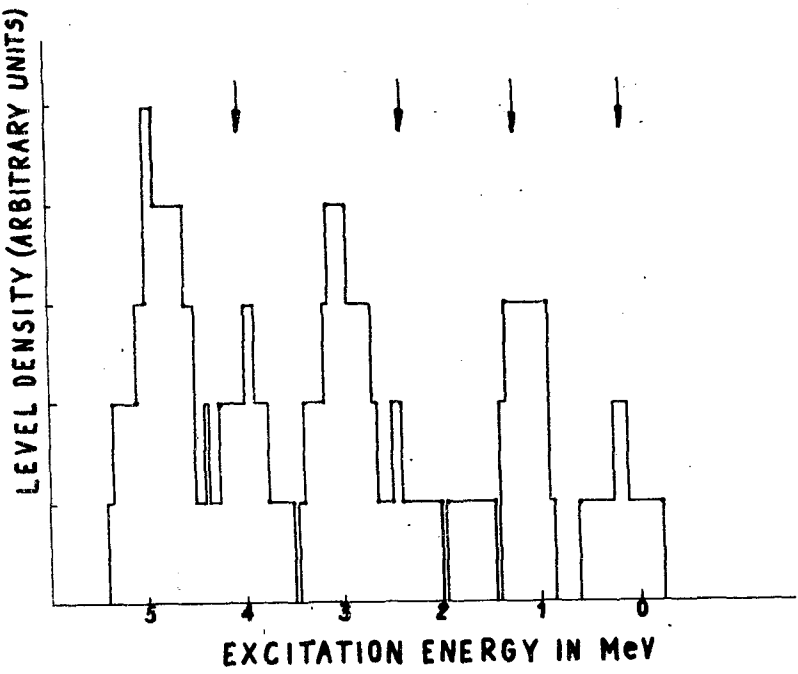

Fig. 3 Single neutron level density vs. the excitation energy of the residual nucleus Eu^{156}. The arrows show the positions of the maxima observed in the α - spectrum.