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AN ANALYSIS OF THE $^{27}Al(n,t)^{25}Mg$ EXCITATION FUNCTION*

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The analysis of neutron-induced charged-particle reactions is very important for developing nuclear reaction theories and also for different applications (such as e.g. activation analysis). In connection with cluster formation in the pre-equilibrium evaporation process, there are still a lot of uncleared points, at present. In order to clear up these obscurities, it is very important to analyse processes simultaneously in all concurrent reaction channels. If only a part of the channels is used, then -- owing to the restriction -- the errors in describing reaction mechanism might induce hidden uncertainties in the model parameters applied. The roles of the concurrent channels will be discussed in the present work by analysing $^{27}Al(n,t)^{25}Mg$ cross-section data.

The available experimental data, from refs. [1-3], can be seen in fig. 1. The results of the first two papers were obtained by using monoenergetic neutrons, while those of ref. [3] were gained from an analysis of integral accumula-

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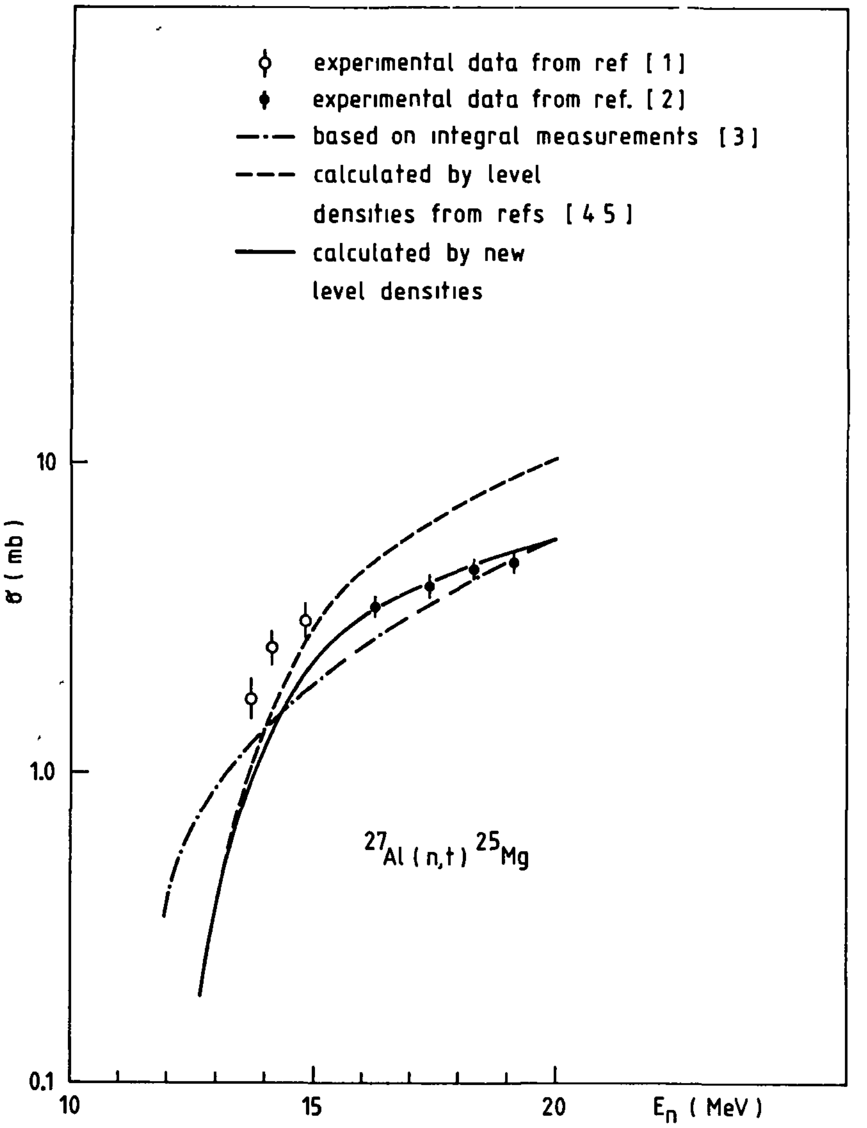

Fig 1

tion of tritium in different neutron fields. In addition to the experimental results, cross-section calculations by the statistical model were also presented in refs. [1-3]; the agreement between theory and experiment is rather good in the case of monoenergetic neutrons [2], but this is not so for results from the integral measurements [3]. It is well known, however, that the statistical model results are rather sensitive for the choice of the level density and also for the inverse reaction cross-section associated with the compound nucleus decay channel to be analysed. Therefore, it is very important to realize how unambigous is the agreement between the results for the (n,t) excitation function calculations and informations on the level densities pertinent to the compound nucleus concurrent reaction channels.

As for the actual level densities, the experimental data available for light nuclei were analysed in such respect [4,5]. For this purpose, the back-shifted Fermi-gas model was used by Vonach and Hille[4], while the most simple exponential parametrization for the energy dependence by Beckerman [5]. Irrespective of the fact, what systematics have been chosen for the level density parameters in the formulae of refs.[4] and [5], the same (n,t) excitation function has been obtained from the statistical model (dashed line in fig. 1.). In the present calculations, the same inverse reaction cross-sections are used as in ref.[2], but another set of the level density paramaters (see below), so the difference between the results can be explained by the new level densities.

Owing to the fact that -- after taking into account the Coulomb-barrier effect -- the (n,t) reaction threshold is very high (it is about 14 MeV), spectroscopical data [6] can be used for the low laying levels of the ^{25}Mg residual nucleus. In such a way, the uncertainties in the residual nucleus level density will appear only above 5 MeV in the triton channel, so, this kind of error will be seen in the (n,t) excitation function at energies higher than 18 MeV only. This means that the disagreement between experimental data and statistical theory -- as shown in fig. 1. -- can be ascribed to the neutron channel. It should be emphasized that -- in the increasing part of the excitation function --

all kinds of non-statistical processes in tritium production have to increase -- and never decrease -- the data estimated by using statistical calculations.

In the analysis of level density systematics -- such as recommended in refs.[4] and [5] -- it is easy to observe that these are based essentially on experimental neutron and proton resonance data. Such data have the drawback that some of the resonances might have been omitted, further that the spin values of the resonances might have been identified with great uncertainty. At the same time, there are such level density data which have been obtained on the basis of an analysis of neutron width fluctuation (see ref. [5]). It is regular that these data are higher than data of resonance origin.

In order to revise the level density parameters used in this paper for calculating excitation functions, width fluctuation data are used together with spectroscopical data for the low-laying levels [6]. New level density parameters were obtained by the back-shifted Fermi-gas model and also by a more consistent approach based on the superfluid model of heated nuclei [7]. It is to be noted that -- by using the same experimental data -- both models give nearly the same estimates of the (n,t) cross-sections in the middle high energy region. So, the use of the back-shifted Fermi-gas model is justified in this way.

The solid line in fig. 1. shows the present results obtained from the statistical model using the above level densities. This result agrees well with the experimental data of ref.[2],

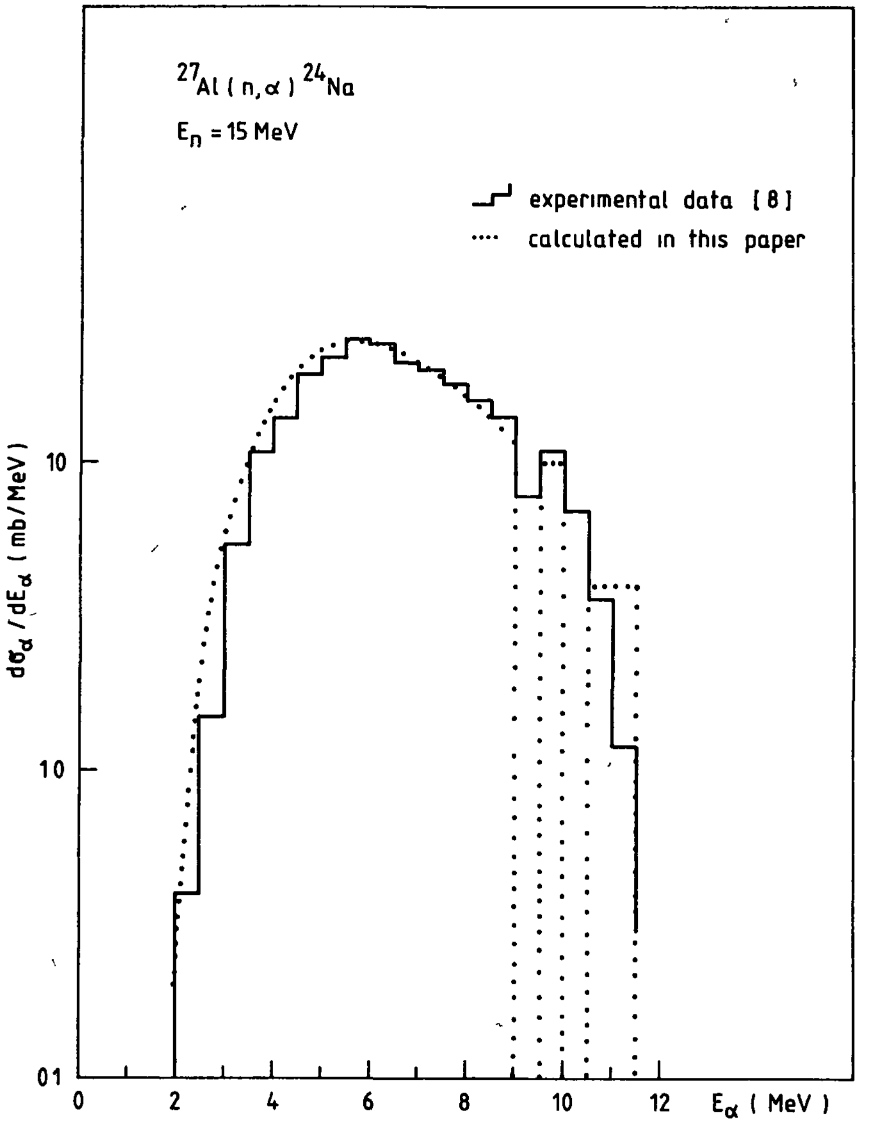

Fig 2

but it is slightly lower than data of ref. [1]. Therefore, in order to check the above level density parameters, the excitation function and the spectrum of the ^{27}Al(n,alpha) ^{24}Na reaction have also been investigated [8]. The obtained alpha spectrum is shown in fig. 2. The present calculations reproduce well the (n,alpha) excitation function, too, up to 18 MeV, and some deviations tend to appear only above this value, which show non-statistical processes in the alpha emission start to contribute here. Also, an analysis has been performed for the inelastic scattering of neutrons on aluminum. Such an analysis, however, did not give any additional information on the level density of the neutron channel. This is in connection with the fact that direct processes of neutron scattering do contribute appreciably at the hard part of the observed spectrum, and the uncertainty of such an analysis does not make it possible to prefer a certain statistical description of the evaporation components in the neutron spectra. This seems to be a general rule of the statistical reaction mechanisms if analysing level densitites in the non-dominant reaction channels, if treating e.g., (n,alpha) and (n,t) reactions.

To sum up the results of the analysis, the conclusion be drawn: it is the statistical mechanism in the emission of clusters which determines -- first of all -- the ^{27}Al(n,alpha) and ^{27}Al(n,t) cross-sections at neutron energies of 18-20 MeV. For a quantitatively correct description of the observed cross-sections, those level densities are essentially needed which are consistent with the width fluctuation analysis for the decays of highly excited nuclei [5]. These level densities are substantially higher than those ones recommended in systematics for light nuclei [4,5]. For obtaining more accurate values of the inverse reaction cross-sections, it is very important to investigate the excitation function near the reaction threshold.

In order to be quite frank, it is to be mentioned here that the ^{235}U thermal fission spectrum averaged ^{27}Al(n,t) cross-section -- as measured by Heinrich and Tanner [10] -- is higher (by about 50 %) than that calculated by the use of the present excitation function (full line in fig. 1.). This integral experimental value [10] can be reproduced better (within 15 %) if using the "purely empirical" excitation function [11] based on the data of both ref. [1] and ref. [2]. Of course, this "counter-

-argument" against the present excitation function is not too strong, because the result of the integral measurement [10] is rather inaccurate having an error of 30 %.

However it may be, to justify (or to query) the excitation function calculated in this paper, it would be very important to re-measure the whole $^{27}Al(n,t)^{25}Mg$ excitation function (from~13 to 19~MeV) within the same experiment, and to eliminate such a way possible discrepancies in data measured up till now.

References

[1] Sudár S. and Csikai J., Nucl. Phys. A319 (1979) 157

[2] Qaim S.M., Wölfle R. and Liskien H., Phys.Rev. C25 (1982) 203

[3] Wölfle R., Sudár S. and Qaim S.M., Nucl. Sci. Eng. 91 (1985) 162

[4] Vonach H. and Hille P. Nucl. Phys. A127 (1969) 289

[5] Beckerman M., Nucl. Phys. A278 (1977) 333

[6] Table of Isotopes, 7th edn (Lederer C.M. and Shirley V.S., Eds) Wiley, New York (1978)

[7] Grudzevich O.T., Ignatyuk A.V. and Plyaskin V.I., Proc. of International Conf. on Neutron Phys., Kiev, USSR, Sept. 1987 (in press)

[8] Grimes S.M. et al., Nucl. Sci. Eng. 62 (1977) 187

[9] Bychkov V.M. et al., Cross-sections for neutron-induced threshold reactions, Energoizdat, Moscow (1982)(in Russian)

[10] Heinrich F. and Tanner F., Helvetia Phys. Acta 36 (1963) 298

[11] Bődy Z.T. and Mihály K., Rep. INDC(HUN)-22/L(1985)