A STUDY OF THE ^{115}In(p, α)^{112}Cd REACTION AT PROTON ENERGY 14 MeV

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Energy spectra of α particles from the reaction ^{115}In(p, α)^{112}Cd were measured at proton energy $E_p = 14$ MeV. A discussion of experimental results in the frame of current nuclear reaction models is given.

1. Introduction

The emission of an alpha-particle under nucleon bombardement of nuclei constitutes an important source of information about nuclear structure. However, reactions of this type are very difficult to interpret. First of all the reaction mechanism is not the same for different nuclei and for different particle energies. This problem was briefly discussed in a survey of Cindro and Kulisić [1]. A comparison of results for (n, α) and (p, α) reactions may facilitate the interpretation as it is reasonable to think that both reactions proceed by the same mechanism for corresponding energies and mass regions. The present paper is a report of the results of an investigation of the ^{115}In(p, α)^{112}Cd reaction.

2. Experiment

The experiment reported here was performed in CEN-Saclay using the experimental arrangement described in [2] and offered kindly at my disposal for these measurements by Dr J. Delaunay and her collaborators.

A 14 MeV proton beam from the Saclay tandem accelerator was used to bombard the target. Reaction products were registered and identified in a telescope which consisted of a surface barier ΔE(50 μm) and a lithium drifted thick silicon detectors equipped with appropriate electronics. The alpha particle spectra were recorded using a multichannel analyser. A 522 μg/cm^2 target enriched to 99% of ^{115}In was used. The energy resolution was approximately 90 keV.

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3. *Results and discussion*

Fig. 1 shows the spectrum of α particles recorded at the laboratory angle of 45°. The Q-value for the ground state transition is +5.9 MeV. The positions of the ^{112}Cd levels known [3] from other types of experiments are indicated. The shape of the spectrum is rather complicated. Up to 3.5 MeV of the excitation energy peaks appear corresponding to the transitions to levels in the final nucleus. No significant peaks are observed above this energy

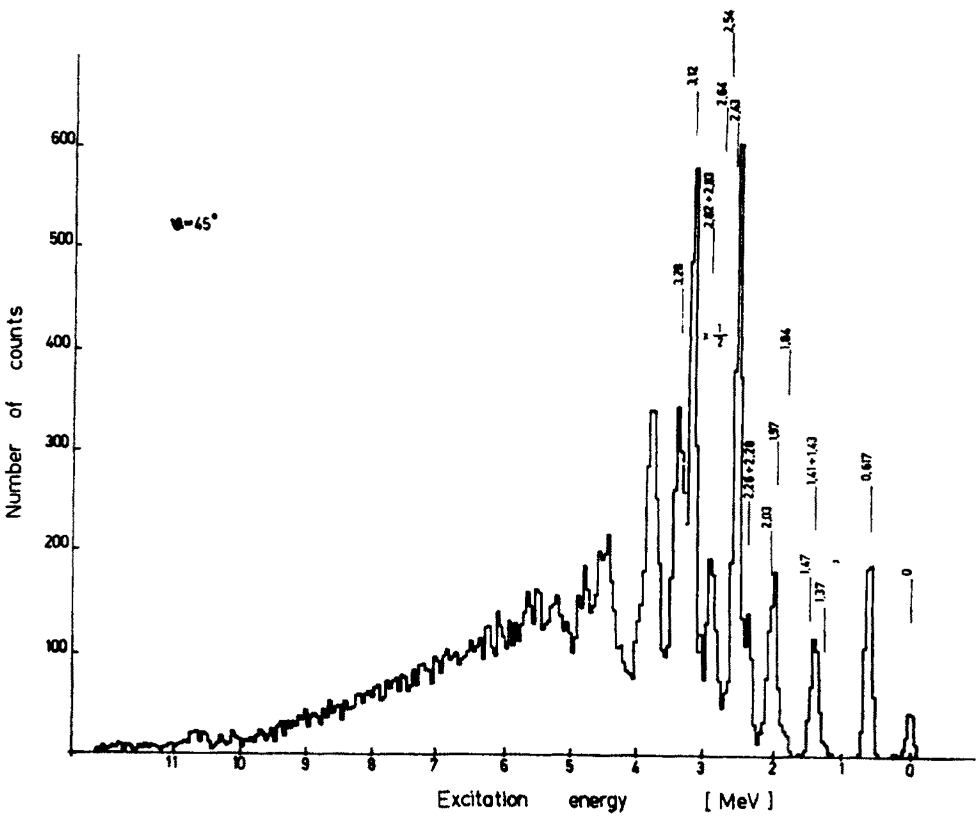


Fig. 1. Spectrum of α particles measured at 45° laboratory angle

An attempt has been made to interpret this spectrum taking into account equilibrium and nonequilibrium processes. The latter have been found necessary to include because of lack of agreement between the experimental spectrum and the simple evaporation spectrum calculated from the expression [4]:

$$N(E) \sim E\sigma_{\text{inv}}(E)\omega(U). \tag{1}$$

The calculations have been performed using two different level densities $\omega(U)$: the first one calculated from the Lang and Le Couteurs formula based on the Fermi gas model [5] and the second one calculated from the super-conductivity model [6]. The cross-section for the inverse reaction $\sigma_{inv}(E)$ was extrapolated from the calculations of Huizenga and Igo [7]. Both curves do not differ significantly and can reproduce only the low energy tail of the spectrum.

The contribution from nonequilibrium process has been calculated on the basis of the excition model of Blann and Griffin [8]. The formula

$$N(E) \sim E\sigma_{inv}(E) \sum_{n=n_0}^{\bar{n}} \left(\frac{U}{E^*}\right)^{n-2} (n+1)(n^2-1) \tag{2}$$

gives the relative probability for particle emission from succesively involved n-exciton states. In our case an additional assumption has been made that the α particle exists in the target as a preformed particle.

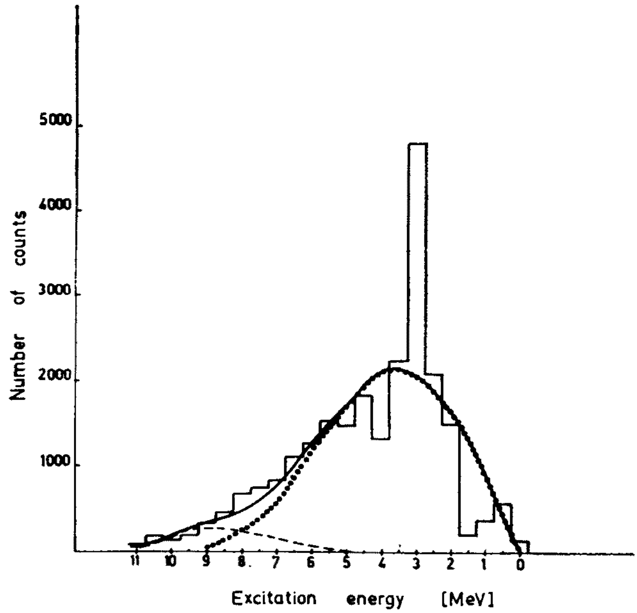


Fig. 2. Comparison of experimental and calculated spectra. The histogram is an experimental spectrum of Fig. 1, but averaged over 0.5 MeV intervals. The dashed curve gives the result of a calculation of the evaporation spectrum (Eq. 1). The dotted line represents the result of a preequilibrium calculation (Eq. 2). Sum of both contributions is shown as a full line

The calculations have been performed taking in Eq. (2) the sum from the first possible term $n_0 = 3$ till $n = 9$. The contributions from terms with higher n were found to be negligible. The calculated energy distribution is shown in Fig. 2 as a dotted line which was normalized to the total number of counts in the experimental spectrum. The comparison was made with the experimental spectrum averaged over 0.5 MeV intervals because the exciton model [8] does not describe transitions to separate levels. To describe the lower part of the spectrum it turned out to be necessary to add a small equilibrium contribution (dashed curve). The full line in Fig. 2 corresponds to the sum of preequilibrium contributions. The overall agreement of shapes of the experimental and calculated spectra is rather good except for the group of levels between about 2.5 MeV and 3.5 MeV.

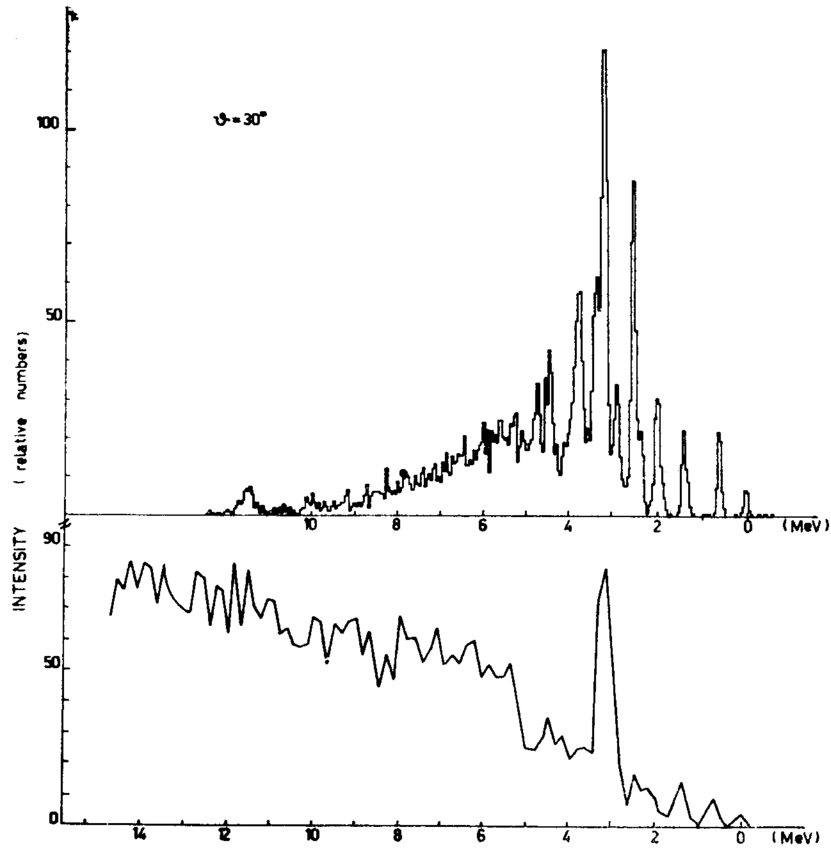
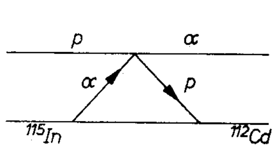


Fig. 3. Comparison of a spectrum measured in this work with a result obtained in Ref. [9]. Both spectra were taken at 30° laboratory angle

This group of levels was also observed as very strongly excited in the experiment on ^{115}In (p, α)^{112}Cd performed at higher proton energy (40 MeV) by Kulisić *et al.* [9]. This is shown in Fig. 3 where the spectra from both experiments obtained at the laboratory angle 30° are compared in the same energy scale. The strong excitation of these levels suggests that they have a preferred configuration in a possible direct process. By analogy to the results obtained for (n, α) reactions in this mass region, one assumes the knock-on mechanism [10]:



The incoming proton knock on an α particle preformed in the target nucleus and is captured into a single particle proton state of the final nucleus. The calculations of the first few levels corresponding to the configuration (1 proton — 1 hole of proton) in ^{112}Cd have been made on the basis of the Nilsson model [11]. The values obtained using the deformation parameter $\delta = 0.05$ are

$$E_{(1p-1h)} = 2.43,\ 2.75,\ 3.22 \text{ and } 3.42 \text{ MeV}$$

in good accordance with the positions of the experimentally observed prominent peaks. Taking into account the sensitivity of these calculations to the deformation parameter (not known for ^{112}Cd) the exact values seem to be of less importance; meaningful is however, that for any deformation from the reasonable interval $\delta = 0.05$–0.15 one obtaines the first few (1p$-$1h) proton levels in the region $E_{exc} = 2.5$–3.5 MeV.

The conclusion from the analysis described above is that the preformed α-particle preequilibrium model with a small contribution of equilibrium evaporation process gives an essentially correct description of the reaction ^{115}In(p, α)^{112}Cd. The contribution from knock-on process is important for the transitions to 2.5–3.5 MeV levels atributed to the excitations of (1p$-$1h) proton states.

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