Experimental Determination of the Normalization Factors for \((\alpha, \tau)\) and \((\alpha, t)\) Reactions.

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In the last years several results from \((\alpha, \tau)\) and \((\alpha, t)\) reaction at energies below 50 MeV have been published (1-4). The analysis of these reaction types can complete our knowledge about the reaction mechanism as well as give us a tool to elucidate the structure of the nuclear states involved. A prerequisite to deduce spectroscopic factors, however, is that the normalization factor of the respective reaction type must be known, which for \((\alpha, \tau)\) and \((\alpha, t)\) reactions is not fulfilled with satisfactory certainty. The normalization factors obtained yet as well experimentally as by calculations (on the basis of Hulthén potentials) are compiled in Table II. Except the value of ref. (1), these normalization factors are deduced from or provided for zero-range DWBA calculations. As the values yet known scatter significantly an investigation at higher energies seemed worth-while for the following reasons: First, the direct-reaction mechanism will dominate. Second, the difference between \(^3\)He particle and triton due to Coulomb interaction becomes more negligible so that a comparison of both reaction types can be made with greater confidence.

We studied the ground-state transitions of the reactions \(^{40}\)Ca\((\alpha, \tau)^{41}\)Ca and \(^{40}\)Ca\((\alpha, t)^{41}\)Sc at an incident energy of 104 MeV. Since for these special transitions the spectroscopic factors are well known (5-7), the normalization factors remain the only free parameters in a zero-range DWBA analysis.

The experimental procedure was similar to that in a previous experiment (6). The target was an isotopically pure foil of 14.1 mg/cm². The outgoing tritons and \(^3\)He particles were detected with a \(dE-E\) telescope which consisted of a 500 \(\mu\)m Si(Li) and a NaI(Tl) scintillation detector. The overall energy resolution was about 1.2 MeV, and the angular resolution was \(< 0.8°\). For the storage and immediate reduction of the measured data we used a CDC 3100 on-line computer which was programmed as a 1024-channel analyser. More details are given in ref. (6).

The differential cross-sections of both ground-state transitions to \(^{41}\)Ca and \(^{41}\)Sc, respectively, were analysed with the code DWUCK (10), which calculates the DWBA matrix element in zero-range approximation. The relation between the measured and the calculated cross-section is given by

\[
\frac{d\sigma}{d\Omega} (\text{exp}) = \text{const} D_0^2 S_{ij} \frac{d\sigma}{d\Omega} (\text{DWBA}),
\]

where \(S_{ij}\) is the spectroscopic factor and \(D_0\) the normalization factor. The constant includes the spins of the nuclear states involved.

For the entrance channel the distorted waves for the DWBA calculations were obtained from optical-model analyses of the 104 MeV elastic \(\alpha\)-particle scattering on \(^{40}\)Ca. The optical potentials chosen were of Woods-Saxon type with a volume absorptive part, so that six parameters had to be adjusted. The angular distribution of the elastic scattering can be well described by two parameter sets which can be distinguished by their real potential depth \(V\) as a shallow and a deep one.

The optical-model parameters for the exit channels had to be taken from the literature. The elastic scattering of \(^3\)He particles on \(^{40}\)Ca has been studied up to an energy of 81.5 MeV, so that an averaged optical-model potential in the case of \(^3\)He could be taken as a good first approximation (11). For the tritons, however, only measurements at energies smaller than 20 MeV are known.

First the DWBA cross-sections for the \((\alpha, \gamma)\) reaction were calculated for a series of helium optical potentials which were available from the literature, but most of which were gained at much lower energies. These were combined with both data sets for the entrance channel and the nuclear overlap was held fixed at \(S = 0.9\) in agreement with ref. (8). Most of the calculated reaction cross-sections are good fits for angles \(\theta \lesssim 30°\), but do not reproduce the experimental cross-sections well enough for larger angles.

As the elastic-scattering angular distribution of the \(^3\)He particles shows, for higher incident energies, a pronounced diffraction pattern similar to that of \(\alpha\)-particles, a misadjustment of the radius parameter \(r_0\) can result in a bad reproduction of the elastic scattering and also of the \((\alpha, \gamma)\) reaction cross-sections. Therefore, we started from the averaged \(^3\)He parameter set and varied the radius parameter \(r_0\). The effect of this variation on the reaction cross-sections is demonstrated in Fig. 1. The angular distributions are calculated with the deep potential in the entrance channel. Taking the shallow \(\alpha\) potential, the calculated \((\alpha, \gamma)\) angular distribution shows more structure, so that the deep \(\alpha\) potential is favoured. There the best fit is obtained for a value \(r_0 = 1.25\) fm; the optical parameters used are listed in Table I. Now the measured angular distribution can be reproduced satisfactorily for all measured angles. There-

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(8) P. D. KUNZ: University of Colorado, unpublished report.