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STUDY OF THE $^{118}$Sn(p, $\alpha$)$^{115}$In REACTION WITH 20 MeV POLARIZED PROTONS

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The analyzing powers in the $^{118}$Sn(p, $\alpha$) reaction leading to five states in $^{115}$In have been measured at $E_p = 20.4$ MeV. The results are well described with DWBA calculations using a cluster form factor.

It is well known that the use of polarized particles in nuclear reactions gives additional information as well on the reaction mechanism as on the spectroscopy of the states involved. In this respect elastic and inelastic scattering and single-nucleon transfer reactions have been studied most extensively. Whereas the inelastic scattering of polarized particles, though relatively easy to perform, gives insight mainly into the reaction mechanism and only after relatively complicated calculations some information on the nuclear wave functions, the single-nucleon transfer reactions obey simple sign rules connected with the angular momentum transfer. Large discrepancies, however, between experiment and DWBA calculations have been encountered sometimes.

Among the two-nucleon transfer reactions ($d$, $\alpha$) has been studied most [2]. The data on ($p$, t) and ($p$, 3He) reactions [3] are rather scarce, due to the large negative $Q$-values, which require proton energies well above 20 MeV. Until now no experimental data on ($\overline{p}$, $\alpha$) reactions, which should be analyzed in terms of direct reactions, have been published.

Recent experiments on Sn(p, $\alpha$)In [4] at 22 MeV proved the spectroscopic usefulness of this type of reaction. The DWBA calculations describing these data predict large analyzing powers with distinct $j$-dependence. We therefore thought it worthwhile to perform a ($\overline{p}$, $\alpha$) experiment with the polarized beam of the Eindhoven cyclotron [5] as a further check on the reaction mechanism and the cluster approximation of the form factor. We chose the $^{118}$Sn($\overline{p}$, $\alpha$)$^{115}$In reaction because this reaction had been studied most extensively with unpolarized protons.

The experiment was done at an energy of 20.4 MeV. Target currents up to 30 nA were used with a polarization of about 80%. The target was a self-supporting $^{118}$Sn foil. The $\alpha$-particles were detected with four 500 $\mu$m surface barrier detectors. The resolution was 150 keV. The spectra were recorded by a PDP-9 computer and analyzed afterwards. The analyzing power for the $^{118}$Sn($\overline{p}$, $\alpha$)$^{115}$In reaction leading to five strongly excited states in $^{115}$In was measured for an angular range from 17° to 80°.

The data were analyzed within the framework of the DWBA with the code DWUCK4 [6]. As in the semi-microscopic model described earlier [4], cluster form factors, generated in a Woods–Saxon well of dimensions $r_0 = 1.25$ fm and $a = 0.45$ fm were used. No spin–orbit term was used in the binding of the transferred “triton”. The same optical potentials were used as in ref. [4], but we also carried out calculations using the global potential of Becchetti and Greenlees [7] modified with a spin–orbit diffuseness of 0.50 fm, because it had been shown that Sn($p$, p) data taken previously in our laboratory were fitted quite well in this way. There were only minor differences in the...
predictions for the ($\vec{p}$, $\alpha$) analyzing powers.

The experimental results together with curves from the aforementioned calculations are shown in fig. 1. The agreement between experiment and theory is surprisingly good in view of the simplifications used, thus corroborating the approximations made in the semi-microscopic model. The $j$-dependence in the analyzing powers of the $J^\pi = 1/2^-$ (0.34 MeV) and $J^\pi = 3/2^-$ (0.60 MeV) states is predicted quantitatively. For the higher angular momentum transfers $L = 3$ ($J^\pi = 5/2^-$, 1.04 MeV) and $L = 4$ ($J^\pi = 9/2^+$, 0 MeV and the $J^\pi = 9/2^+$ doublet at 1.45 and 1.49 MeV), the
sign of the analyzing powers is described correctly, but the predicted analyzing powers are slightly larger in absolute value than shown by the experiment. This effect, together with the differences in the experimental analyzing powers for the $9/2^+$ states might point to a certain sensitivity to the detailed microscopic structure of the states involved. The $J^m = 5/2^-$ state at 1.04 MeV could not be resolved in our experiment from the $J^m = 5/2^+$ and $J = 11/2^+$ states at 1.08 and 1.14 MeV, respectively, but the cross sections for the latter states are an order of magnitude smaller [4]. Since the analyzing power for a $5/2^+$ transition has the same shape, but opposite sign as that for a $5/2^-$ transition, this result strongly supports the $J^m = 5/2^-$ assignment for the 1.04 MeV state [8].

Concluding we may say that this work — a first direct $(p, \alpha)$ experiment — indicates the usefulness of the $(p, \alpha)$ reaction as a spectroscopic tool. Whereas the angular distribution is known to be strongly $j$-dependent [9], but usually does not allow to discriminate between positive and negative parity, a polarization experiment yields this result from the sign of the analyzing power.

Another interesting aspect is that the analyzing powers show much more structure than the angular distributions, which are, except for the $1/2^-$ state, rather featureless. Combined with the fact that the $(p, \alpha)$ reaction can excite seniority $v = 3$ states not reached with single-nucleon transfer reactions or seniority $v = 1$ states two neutrons extra away from the stability line, these measurements open new prospects.

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