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Isospin breaking in the analyzing power of $^3H(^3He,^2H)^4He$ and the inverse reaction

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We have performed a microscopic calculation for the reaction $^3He+{}^3H \rightarrow d+\alpha$ with special emphasis on recent measurements by Rai *et al.* of the analyzing power. A detailed comparison is given with the $\vec{d}+\alpha \rightarrow {}^3He+{}^3H$ reaction. The dynamics responsible for deviations from isospin symmetry in the two reactions manifests indeed in different ways. A comparative analysis seems to allow for a better determination of a specific matrix element responsible for the apparent isospin breaking effects in the $^3He+{}^3H \rightarrow d+\alpha$ reaction.

In a recent paper[1] the reaction $^3H(^3He,^2H)^4He$ has been studied and an apparent violation of isospin symmetry has been found; also the inverse reaction $^4He(^2H,^3He)^3H$ (Ref. 2) has been studied in connection with the Barshay-Temmer theorem,[3] as a test of isospin symmetry. In Refs. 2 and 4 we reported on a resonating group calculation of the ^6Li system, where we used a semirealistic nucleon-nucleon potential containing central, spin-orbit, and tensor terms. We allowed many coupled channels formed from the fragmentations ^4He-^2H, ^5Li-n, ^5He-p, ^3He-^3H, and excited ^5Li and ^5He ones.[2,4] The relative thresholds are well reproduced and charge symmetric channels have different thresholds, due to the Coulomb energy.

Whereas time reversal invariance relates the cross sections of the conjugate reactions, so that they contain the same information if time reversal invariance holds, this is no more true when analyzing powers are measured. The asymmetries in cross sections and analyzing powers originate from interference of even and odd parity matrix elements. Whereas the reaction $^3H(^3He,^2H)^4He$ has been analyzed phenomenologically, it was demonstrated, in a microscopic analysis of the $^4He(^2H,^3He)^3H$ reaction,[4] that the even parity matrix elements are an order of magnitude larger than the odd parity ones. If one measures the deuteron analyzing power in the reaction $^4He(^2H,^3He)^3H$ and does not measure the polarization of one of the particles in the exit channel, then different channel spins in the exit channel may not interfere.[2] Hence, only non-spin-flip odd parity matrix elements can contribute to the observed asymmetry.[2] At variance the analyzing power of ^3He in the reaction $^3H(^3He,^2H)^4He$ is sensitive to the interference of the two channel spins in the entrance channel. Therefore in addition to the non-spin-flip odd parity matrix elements, also the spin-flip odd parity matrix elements might contribute to the observed asymmetry.[1] In the calculations, the spin-flip odd parity matrix elements turned out to be a factor 2–3 times larger than the non-spin-flip ones,[2] hence in the $^3H(^3He,^2H)^4He$ the asymmetries might be much larger than those observed in the deuteron analyzing power.

We applied the matrix elements calculated in Refs. 2 and 4 to the inverse reaction $^3H(^3He,^2H)^4He$ in order to study the possible interference of spin-flip and non-spin-flip odd parity matrix elements with the even parity ones. In Fig. 1 we present the calculated analyzing powers at

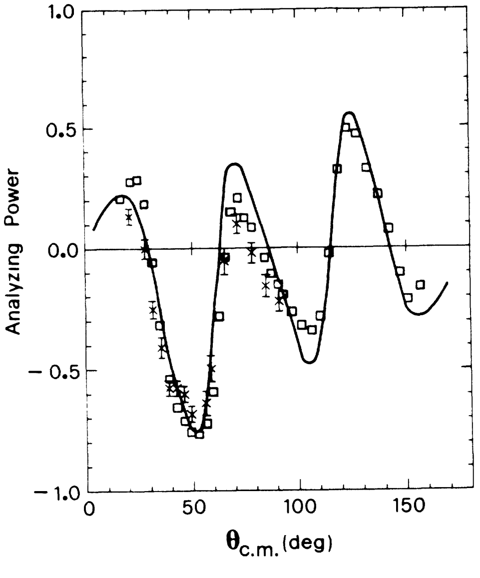

FIG. 1. Analyzing powers of the $^3H(^3He,^2H)^4He$ reaction at 18 MeV incident energy. The crosses are experimental data taken from Ref. 1 and the continuous line is the result of the calculation. As in Ref. 1 we also present the experimental data of Ref. 5 at 17 MeV.

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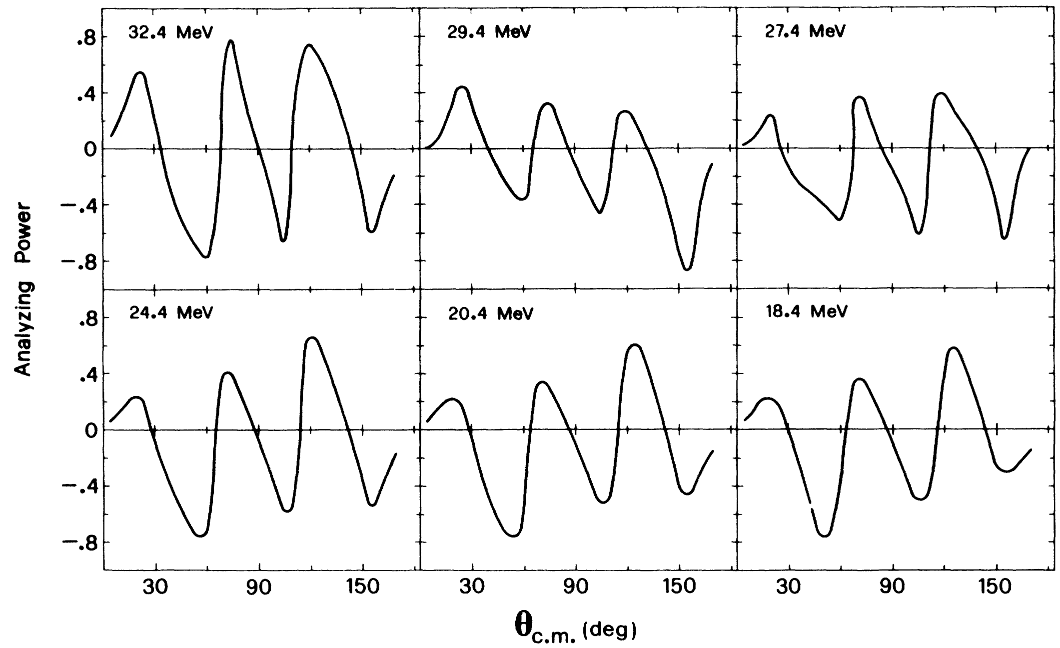

FIG. 2. Calculations of analyzing powers of the ^{3}H(^{3}He,^{2}H)^{4}He reaction at different energies.

an incident energy of 18 MeV and compare to the data of Ref. 1 and to previous measurements at 17 MeV.[5] The agreement is satisfactory.

Calculations for the energy dependence of the analyzing power are displayed in Fig. 2, which can be compared with the data of Ref. 1. The trend of the data is adequately reproduced by the calculations. In particular the zero crossing point around 90° discussed extensively in Ref. 1 is somewhat shifted to smaller angles. The shift decreases with increasing energy as in the data in Ref. 1. However, the calculated shift never exceeds 5°.

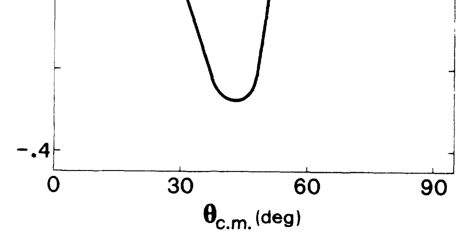

FIG. 3. Effect of the S^3_{330} matrix element on the analyzing power asymmetry at 18 MeV. Continuous line corresponds to calculations which include S^3_{330} matrix element, while the dashed one is obtained when $S^3_{330}=0$.

In Ref. 2 it was shown that the asymmetries of the cross sections

$$W(\theta)=\frac{\sigma(\theta)-\sigma(\pi-\theta)}{\sigma(\theta)+\sigma(\pi-\theta)}$$

and of the analyzing powers

$$D(\theta)=A_y(\theta)+A_y(\pi-\theta)$$

of the reaction ^{4}He(^{2}H,^{3}He)^{3}H originate mainly from the interference of S-matrix elements of negative parity S^2_{111}, S^2_{331}, S^3_{331}, and S^4_{331} with the positive parity ones S^3_{221}, S^2_{221}, and S^3_{441}. Here we denote $S^J_{l_i l_o s}$ as the S-matrix element of total angular momentum J, incoming l_i and outgoing l_o orbital angular momenta and s the ^{3}He+^{3}H channel spin. For the ^{3}H(^{3}He,^{2}H)^{4}He reaction we investigated the importance of the different matrix elements. In Fig. 3 we present a comparison between the full calculation of the asymmetry $D(\theta)$ of the ^{3}He analyzing power with a calculation where the matrix element S^3_{330} has been put to zero.

We thus conclude that the spin-flip matrix element S^3_{330} plays the dominant role in the apparent violation of isospin symmetry found in Ref. 1. The other matrix elements give a smaller contribution, of the same order of the asymmetry found in the ^{4}He(^{2}H,^{3}He)^{3}H reaction. Therefore a comparison between the two reactions can provide information on the value of S^3_{330} directly from the data and thereby provide more stringent constraints for the theoretical calculations.

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