Cross section and induced polarization in ^{3}He elastic scattering at 443 MeV

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Study of the spin dependent interactions in nucleon- and nucleus-nucleus scatterings is one of the fundamental subjects in nuclear physics because they are closely related to the nuclear structure and reaction mechanism. However, for ^{3}He-nucleus elastic scattering at intermediate energies, where the experimental data are limited to differential cross sections, optical model calculations showed that experimental data were well reproduced without the spin-orbit term [1]. Therefore the spin-orbit term of the optical potential is experimentally not yet fixed. Measurements of polarization observables in ^{3}He scattering are limited at 33 MeV [2, 3]. Recently, the effects of the spin-orbit interactions on the elastic scattering of ^{3}He from heavy-mass nuclei at intermediate energies have been theoretically studied based on the folding models [4]. Calculations showed that the predicted analyzing power reached almost the maximal value of $A_y = 1$ around 20°-30° in the center-of-mass system. Such a large analyzing power could make the investigation of the spin-orbit interaction reliable. In the present study, we measured the angular distributions of the differential cross section and the induced polarization of elastically scattered ^{3}He on ^{12}C, ^{58}Ni, and ^{90}Zr targets at 443 MeV (RCNP-E157, E182 and R38).

The experiment was performed at RCNP with the spectrometer Grand Raiden and its focal plane (FP) detector and Focal Plane Polarimeter (FPP) system. The polarization was measured by the double scattering method. The calorimeter was constructed after MWPC4 in order to measure the total energy of the scattered ^{3}He particles on the analyzer. The calorimeter consisted of three planes of plastic scintillators and was thick enough to stop all ^{3}He particles.

Preceding the polarization measurements, the effective analyzing power of the FPP system was determined for ^{3}He [5]. The effective analyzing power was determined to be $A_y^{eff} = 0.232 \pm 0.010\ ^{+0.017}_{-0.015}$, where the first and second uncertainties represent the statistical and systematic ones, respectively. The systematic uncertainties were estimated from those in the absolute polarization value.

The experimental results in the center-of-mass system for the differential cross section ($d\sigma/d\Omega$) and the induced polarization (P_y) are shown as closed circles with statistical errors in Figs. 1 and 2, respectively. The differential cross section for the ^{12}C target in Fig. 1 was measured in a previous experiment [6]. The solid curves in Figs. 1 and 2 represent the calculated differential cross section and polarization with the optical potential. Potential parameters were determined by fitting the experimental data so as to minimize the chi-square. In this calculation, we employed the complex spin-orbit potentials with full Thomas form to obtain the best-fits to the polarization. The diffuseness parameter of the spin-orbit potential was about 0.6-0.8 fm for all three nuclei at the present energy, and the anomalously small values around 0.2 fm, that has been reported in studies at 33 MeV [2, 3], could not describe the present data.

The experimental data were compared with single folding (SF) model calculations. In this model, the potential between the ^{3}He and nucleus was obtained by folding the proton-nucleus optical potential at 150MeV by the nucleon density distribution of ^{3}He. In the SF model calculations, renormalization factors are introduced to modify the real central, imaginary central, and spin-orbit term, respectively. The results are shown as the dashed curves in Figs. 1 and 2. The real central terms had to be reduced by 15-20% to obtain best-fits for ^{58}Ni and ^{90}Zr, while the imaginary central potentials had not to be modified. For ^{12}C, the optimum renormalization factors were very different from the other, heavier nuclei. The real potential was strengthened by 60% and the imaginary potential was reduced by 20%. This might come from the fact that the p-^{12}C optical potential is not usually described by the global parametrization. The SF spin-orbit potentials were reduced by 30-40% to give best-fits for all nuclei. The necessity of renormalization may be attributed to the fact that the SF potential doesn't include any density dependence of the nucleon-nucleus interaction in the ^{3}He nucleus.

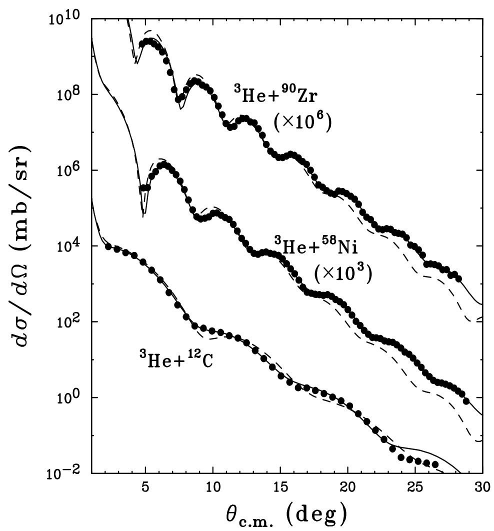

Fig. 1: Differential cross sections of ^{3}He elastic scattering from ^{12}C, ^{58}Ni, and ^{90}Zr at 443 MeV incident energy. The solid and dashed curves show the results of the optical model and SF model calculations.

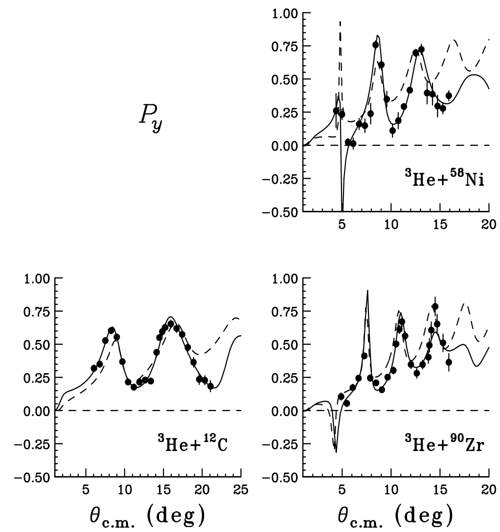

Fig. 2: Induced polarizations of ^{3}He elastic scattering from ^{12}C, ^{58}Ni, and ^{90}Zr at 443 MeV incident energy. The solid and dashed curves show the results of the optical model and SF model calculations.

References

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