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7.3 Analyzing Power Measurements In Proton Capture Reactions

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Recently we reported[1] on the similarity between proton captures into one-particle one-hole, 1p-1h, states in ^{12}C and proton capture into single-particle states in the neighboring nucleus, ^{13}N. Experience [2,3,4] has shown that in medium energy capture reactions of this type, the states most strongly populated are 1p-1h states of the closed-subshell nuclei and the single-particle states of the closed-subshell-plus-one nucleon nuclei. These results are in accordance with the assumptions of the empirical direct-semi-direct, DSD, model of capture reactions. It is assumed in this model that the nucleons are captured into definite shell-model orbitals while the target nucleons remain as spectators, i.e., are not excited during the capture. In this simple independent-particle picture, the spectrum of a (p,γ) reaction into a closed-subshell-plus-one-proton nucleus would be expected to resemble that for capture into the neighboring closed-subshell nucleus, except that the simple single-particle configurations seen as final states in the former case are spread out by the particle-hole coupling in the latter. The modified DSD model for nucleon capture, described in reference 1, produces relationships between proton captures into any pair of related single-particle and 1p-1h states of adjacent nuclei. If the two transitions are compared under similar, if not identical, kinematic conditions, then the model yields equal analyzing powers for the transitions and a constant ratio of the cross sections, related to spectroscopic and state-population factors,

i.e.,
$$A_y(J_i, j_f, J_f) = A_y(0, j_f, j_f)$$

where the initial state is specified by the angular momentum and isospin quantum numbers of the target ground state (J_i, M_i, T_i, T_{i3}) and the quantum numbers of the incident nucleon $(s_i, m_s, t = 1/2, t_3)$; the final state is specified by the quantum numbers (J_f, M_f, T_f, T_{f3}). Since $J_i = 0$ for the target in transition into a nucleus with a closed shell plus one nucleon, this transition proceeds via capture to a unique final orbital with $j_f = J_f$. In order to distinguish this j from J for the closed shell case, we use $j_f = j = J_f$.

Polarized beams of protons from the Indiana University Cyclotron were used to bombard solid targets of ^{27}Al and ^{28}Si at an energy of 20.8 MeV. The emitted gamma rays were detected by The Ohio State University Medium Energy gamma assembly, consisting of a 25 cm diameter by 30 cm long NaI(Tl) crystal surrounded by a plastic annulus. The annulus served as an anti-coincidence shield for background and cosmic-ray rejection. The detector system utilized time-of-flight information to reject neutron-induced events; the time resolution was 2.3 ns and provided good discrimination between gamma-ray and neutron events at all bombarding energies. The detector was positioned 1 m from the target and subtended a solid angle of 9.16 msr. The detector resolution was about 3.5% FWHM.

The reactions studied were the $2S_{1/2}$ proton capture in the $^{27}Al/^{28}Si$ system populating (a) the $1/2^+$ ground state of ^{29}P and the first-excited 2^+ state in ^{28}Si; and (b) the $1d_{3/2}$ proton capture populating the $3/2^+$ first-excited state in ^{29}P and the second-excited 4^+ state in ^{28}Si. The results of the analyzing power angular distributions for the pairs of similar proton captures are shown in Fig. 1. The solid curves in the figure are calculated using the DSD computer code HIKARI[2].

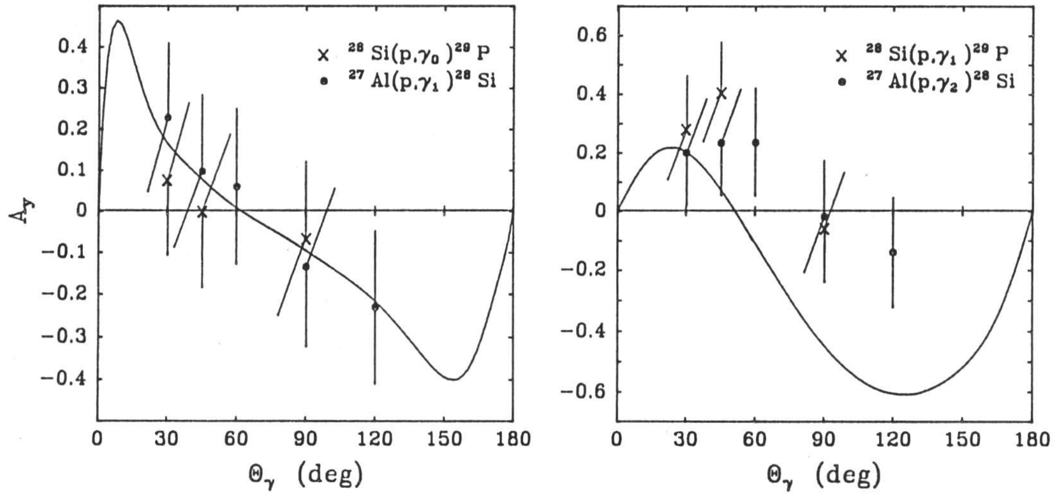

Fig. 1. Analyzing Powers for the $2S_{1/2}$ and $1d_{3/2}$ proton captures in ^{27}Al and ^{28}Si.

References

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