On the Polarization of Protons in \((d, p)\) Stripping Reactions.

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The polarization of outgoing protons in stripping nuclear reactions with unpolarized target nuclei and an arbitrary polarized incident deuteron beam is considered (*).

To get the quantities \(\langle T_{k^x} \rangle_{k^x'} = 0.1; -k^x < k^x' < 2k^x \) (\(\langle T_{k^x} \rangle\) is the average of the \(T_{k^x}\) component of a tensor operator in the system of particles with a given spin) defining the polarization of protons in the exit channel we use the known formula

\[
\langle T_{k^x} \rangle = \frac{\text{Tr}(T_{k^x} F g_{in} F^+)}{\text{d}\sigma/\text{d}\Omega},
\]

where \(g_{in}\) is the density operator of the entrance channel, \(F\) the scattering amplitude for the process, and \(\text{d}\sigma/\text{d}\Omega\) the angular distribution of protons given by

\[
\frac{\text{d}\sigma}{\text{d}\Omega} = \text{Tr}(F g_{in} F^+) \text{ Tr}(T_{k^x} F g_{in} F^+).\]

As we consider the reaction with unpolarized target nuclei, \(g_{in}\) is given by

\[
g_{in} = \frac{1}{I_d} g_d (**),
\]

where \(g_d\) is the density operator of deuterons for which we use the expansion:

\[
g_d = \frac{1}{\sqrt{2}} \sum_{\lambda=0}^{\lambda} \sum_{\lambda=-\lambda}^{\lambda} \langle T_{k^x} \rangle T_{k^x}^d.
\]

(*) The work was reported at the Congress of Mathematicians and Physicists of Yugoslavia, 19-21 September 1960, Belgrade.

(**) We use the abbreviation \(\mathfrak{F} = (2x + 1)^{1/2}.\)
For the scattering amplitude $F$ we take the scattering amplitude obtained by the distorted-wave Born approximation with zero-rang approximation for the $V_{np}$ interaction.

We suppose that the $V_{np}$ interaction contains a polarizing, $l$-$s$ coupling term, but for the sake of simplicity we take only the spherically symmetric potential for the $V_{np}$ interaction.

For the trace appearing in the expression (1) we get the following results:

\[ \text{Tr} \left( T_{np}^2 F \right) = N^2 \sum_{\lambda} \sum_{\lambda'} \lambda' \overline{\lambda} \exp \left[ i (\sigma_{l\alpha} + \sigma_{l\beta} - \sigma_{l\alpha} - \sigma_{l\beta}) \right]. \]

\[ \cdot \mathcal{A}(l_n, l_p, j_n, j_p, j_d) \mathcal{A}^*(l_n, l_p, j_n, j_p, j_d) \langle T_{np}^2 \rangle (l_n 0 l_p 0 | l_d 0). \]

\[ \cdot (l_n 0 l_p 0 | l_d 0) (l_n 0 l_p 0 | p 0) (l_n 0 l_d 0 | d 0) (l_n 0 l_p 0 | p 0) (l_n 0 l_d 0 | d 0) (-1)^{l_n + l_p + l_d} \mathcal{D}_{snp}^2(\Phi, \Theta, 0). \]

Putting $\lambda' = \lambda = 0$ in the formula (4) we obtain the angular distribution for protons (arbitrary polarized deuterons) (1).

\[ \mathcal{A}(l_n, l_p, j_n, j_p, j_d) \]

where the second sum runs over $l_n, j_n, l_p, j_p, l_d, j_d, l_d, j_d, a, e, f, p, d$ and $g$ with these restrictions on the sum over $l_n, j_n$:

\[ (-1)^{l_n} = II, \]

following from the conservation laws for angular momenta and parities.

The quantities $\mathcal{A}(l_n, l_p, j_n, j_p, j_d)$ are given by

\[ \mathcal{A}(l_n, l_p, j_n, j_p, j_d) = \kappa_p k_d \int_{k_n}^{k_n} \frac{d r}{r} \left( k_p, \frac{M_i}{M_f} \right) \left( k_d, r \right) r^2 dr, \]

where $k_p$ and $k_d$ are proton and deuteron wave numbers, respectively, for the corresponding relative motions in the c.m. system. $\kappa_n$ is given by $\kappa_n^2 = 2 M_n \varepsilon_n / \hbar^2$, where $\varepsilon_n$ is the binding energy for the captured neutron. $u_{l_p, i_p}(k_p; r_p)$ and $u_{l_d, i_d}(k_d; r_d)$ are solutions of the radial Schrödinger equation containing the appropriate potential for the $V_{np}$ or $V_{pd}$ interactions, respectively (including the Coulomb interaction). $T_{np}^2$ are components of the tensor operator in the co-ordinate system in which the $z$ axis lies along the vector $k_n$. $T_{np}^2$, however, are components in the co-ordinate system in which the $z$ axis lies along the vector $k_n$ and the $y$ axis along the vector $k_x \times k_z$. These two co-ordinate systems are connected by Eulerian angles ($\Phi, \Theta, 0$) where $\Phi$ and $\Theta$ are scattering angles.

Putting $\lambda' = \lambda = 0$ in the formula (4) we obtain the angular distribution for protons (arbitrary polarized deuterons) (1).

(1) These two particular cases are treated in the article by L. J. B. Goldfarb and R. C. Johnson: Nucl. Phys., 18, 353 (1960).