Absorption and polarization phenomena in knock-on reactions

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A method is proposed for establishing the quasielastic character of the knock-on reaction. The method is based on the strong dependence of the effective polarization of the knock-on particle on its total angular momentum, and is suitable even in the presence of strong absorption in the initial and final states.

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The first results on reactions of the type $(p,2p)$ on polarized protons at energies 635 MeV have recently been reported for ^{12}C and ^{6}Li[1] and at 200 MeV for ^{16}O,[2] and the data for low energy reveal a strong dependence of the cross section on the total angular momentum j of the knocked-out proton. A similar phenomenon, apparently connected with the substantial role of absorption, was predicted in[3,4] (see also[5]).

It might seem that the presence of a strong interaction in the initial and final states makes it more difficult to establish the mechanism of the reaction. This is only partially true, however. If it is possible to investigate ion effects, then a general method can be proposed for ascertaining that the investigated process is indeed connected with quasielastic knock-on. More accurately speaking, it can be shown that any aggregate of graphs containing a quasielastic-scattering block (it is shown dashed in Fig. 1) and "dressed" by arbitrary rescatterings at the beginning and at the end leads to the same dependence on the quantum numbers of the nucleus as simple inelastic scattering of the incident particle by the nuclear protons, but having only a certain effective polarization $\mathbf{P}_{eff}$. (The expression for the amplitude corresponding to the indicated aggregate of graphs, at a fixed momentum of the residual nucleus, coincides formally, apart from a constant factor, with the expression for the pole diagram, in which the incident proton is scattered by a polarized nuclear proton, and the polarization $\mathbf{P}_{eff}$ of the latter is determined by the secondary rescatterings.) The only requirement

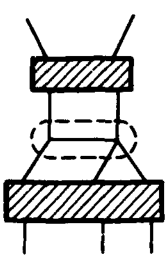

FIG. 1.

is that all the secondary rescatterings be described by central potentials, i.e., that they leave the spin states of the particles unchanged. It is of particular interest that $\mathbf{P}_{\text{eff}}$ depends in a very simple fashion on the total angular momentum of the transferred proton (i.e., on the geometric sum of the proton spin and its orbital angular momentum l). With the aid of a technique similar to that described in[6–8] it is easy to obtain the ratios of P_{eff} at different j:

$$\frac{(P_{\text{eff}})_j}{(P_{\text{eff}})_{j'}} = (-1)^{j-j'} \frac{\begin{Bmatrix} 1/2 & 1/2 & 1 \\ l & l & j \end{Bmatrix}}{\begin{Bmatrix} 1/2 & 1/2 & 1 \\ l & l & j' \end{Bmatrix}},$$

from which we get for $j=l\pm\frac{1}{2}$

$$(P_{\text{eff}})_{j=l+1/2} / (P_{\text{eff}})_{j=l-1/2} = -l/(l+1).$$

For the two p states of oxygen we have $(P_{\text{eff}})_{1p_{3/2}}/(P_{\text{eff}})_{1p_{1/2}} = -\frac{1}{2}$. The last result was noted also in[5]. The factor $-\frac{1}{2}$ is not cited in[4], but is in good agreement with the available results of numerical theoretical calculations. The same relation is well satisfied also experimentally in the $(p,2p)$ reaction on ^{16}O.[2] (We note that the determination of the ratio of the values of the effective polarizations of the proton from the data of[2] is facilitated by the fact that the experiment was carried out under conditions when the cms proton scattering angle was close to 90°, so that the dependence of the cross section on the polarization was left with only one term containing the product of the polarizations of the incident and nuclear protons).

All the foregoing has pertained to a reaction induced by polarized protons, i.e., to the class of polarization phenomena at the vertex (see Fig. 1) in which the fast particle enter. As noted earlier,[6,9,10] both to establish the mechanism and to obtain new information on the structure of the nucleus the greatest interest attaches to an investigation of polarization phenomena that pertain to the nuclear vertex, i.e., to polarization and quadrupolarization of the residual nuclei and to asymmetry in reactions on a polarized target. The corresponding formulas given in[6,8] for the pole mechanism can be generalized to the case of any mechanism (including strong absorption) that reduces to the appearance of effective polarization of the intranuclear proton. To this end it is necessary to replace the quantity P_i in the formulas (the polarization of the protons in elastic pp scattering) by

$$(\mathbf{P}_i - \mathbf{P}_{\text{eff}})/(1 - \mathbf{P}_i \mathbf{P}_{\text{eff}}).$$

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