Dependence of the cross section for quasielastic cluster knockout from atomic nuclei at high energies on the orientation of the recoil-nucleus momentum

N. F. Golovanova, I. M. Il'in, V. G. Neudachin, Yu. F. Smirnov, and Yu. M. Chuvil'skiĭ

Nuclear Physics Institute of the Moscow State University

(Submitted June 2, 1975)
Pis'ma Zh. Eksp. Teor. Fiz. **22**, No. 2, 112–114 (July 20, 1975)

Within the framework of the theory developed in [1] for quasielastic cluster knockout from nuclei by fast hadrons, a new qualitative rule is derived, namely that the cross section depends on the angle between the incident beam and the recoil-nucleus momentum; this dependence was never investigated experimentally before.

PACS numbers: 24.50.

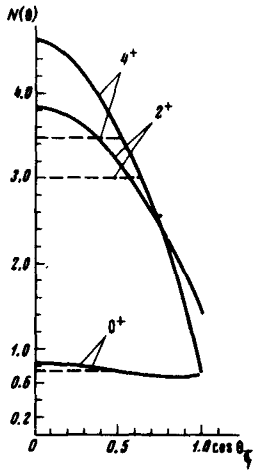
We wish to report here a new effect, which should be observed in reactions of quasielastic knockout of clusters by hadrons at high energies. We base ourselves on the quasielastic-knockout theory proposed in[1], which takes into account, within the framework of the Glauber-Sitenko multiple-scattering theory, the possibility of "de-excitation" of a virtual excited cluster in a nucleus during the course of multiple scattering of a fast particle by the nucleons making up the knocked-out cluster. We thus take into consideration processes more complicated than a simple pole diagram (the possibility of such complications were emphasized many times[2]).

Considering that region of the momentum $\mathbf{p} = \mathbf{p}_1 - \mathbf{p}_2$ transferred to the nucleus, in which b-fold scattering predominates strongly, we write down an expression for the quasielastic-knockout cross section in the form (neglecting the distortion of the waves of the incident and emitted particles):

$$\frac{d\sigma}{d\Omega_a\, d\Omega_b\, dE_a} = \frac{mk_2}{\hbar^2}\cdot\frac{1}{2J+1}\,\overline{\left|F_{a\beta}(\mathbf{q})\right|^2}\left(\frac{d\sigma_{ab}(\mathbf{p})}{d\Omega_a}\right),$$

$$\frac{1}{2J+1}\,\overline{\left|F_{a\beta}(\mathbf{q})\right|^2} = \langle T_1 M_{T_1} T_0 M_{T_0} \mid T M_T \rangle^2 \binom{A}{b}\frac{1}{4\pi} \times \sum_{\mathcal{L} j l}\begin{pmatrix} L_1 & S_1 & J_1 \\ \mathcal{L} & S_0 & j \\ L & S & J \end{pmatrix}^2 (-1)^{\mathcal{L}+l} P_l(\cos\theta) \tag{1}$$

$$\times \sum_{\substack{n\Lambda n'\Lambda' \\ L_0 L'_0}} \langle \dot{A} a N L S T \mid A - b\,\beta N_1 L_1 S_1 T_1;$$



Dependence of the quantities $N_{\alpha\beta}(\theta) = [4\pi/(2J+1)] \times \int |F_{\alpha\beta}(q,\theta)|^2 q^2\, dq$ on the angle θ in the reaction $^{16}O(p, p\alpha)^{12}C$ with excitation of the levels 0^+ (gnd. st), 2^+ (4.4 MeV), and 4^+ (12 MeV). The dashed lines show $N^{\text{eff}}(\alpha) = \int d\Omega N_{\alpha\beta}(\theta)$ for the corresponding transitions.

$$n\Lambda,\ bN_0L_0S_0T_0 \,|\, \mathcal{L} \,|\rangle \langle A\alpha NLS'T \,|\, A - b\beta N_1L_1S_1T_1;\ n'\Lambda',$$
$$bN_0'L_0'S_0T_0 \,|\, \mathcal{L} \,|\rangle \sqrt{(2\Lambda+1)(2\Lambda'+1)} \langle \Lambda 0 \Lambda' 0 \,|\, l0 \rangle \langle L_0 0 L_0' 0 \,|\, l0 \rangle$$
$$\times \begin{Bmatrix} \Lambda \Lambda' l \\ L_0 L_0' \mathcal{L} \end{Bmatrix} R_{n\Lambda}(q) R_{n'\Lambda'}(q)\, C^b_{N_0L_0} C^b_{N_0'L_0'} \Big/ (C^b_0)^2, \qquad (2)$$

where $R_{n\Lambda}(q)$ is the Fourier component of the wave function of the mutual motion of the subsystems $(A-b)$ and b in the initial nucleus, the brackets $\langle | \rangle$ denote the many-particle TISM affinity coefficients (f, p, c), and

$$C^b_{N_0L_0} = \int \Phi^{b^*}_{\text{fr}}(0,0,z)\, \Phi^b_{N_0L_0}(0,0,z)\, dz, \quad z \equiv \{z_1, \ldots, z_{b-1}\} \qquad (3)$$

is the specific overlap integral of the internal wave function of the free cluster b and the virtual excitation of the cluster b in the initial nucleus. In this integral, for each Jacobi coordinate, only the z-component is different from zero.

It is owing to the terms with $L_0 \neq 0$ in (2) that a very strong connection appears between the cross section and the angle θ between the incident beam $\mathbf{p}_1$ and the recoil-nucleus momentum $\mathbf{q}$ (see the figure).

This relation, which is typical of the knockout of d, t, and α clusters from nuclei of the middle and end of the p shell, was never investigated before for the knockout of clusters, and it would be of interest to observe it. This effect is the consequence of the compound nature of the emitted particles, and is missing in the well-investigated reactions of quasielastic knockout of nucleons $(p, 2p)$ if the momenta transferred to the residual nucleus are not large, so that the pole mechanism predominates (see[2] concerning this question). The effect should likewise be missing in the case of knockout of d, t, and α clusters from the ^6Li nucleus $(L_0 = 0)$.

It is easy to consider also the range of values of p in which the multiplicity is smaller than b. In that case not all the Jacobi coordinates in the integrals of (3) are left with z-components only, and the dependence on θ changes. In the region of interference of different multiplicities, say b and $b-1$, the results depend already on the orientation of both $\mathbf{p}$ and $\mathbf{q}$ relative to $\mathbf{p}_1$.

[1]N. F. Golovanova, I. M. Il'in, V. G. Neudachin, and Yu. F. Smirnov, ZhETF Pis. Red. 20, 674 (1974) [JETP Lett. 20, 310 (1974)] Yad. Fiz. [Sov. J. Nuc. Phys.] 22, No. 4 (1975).
[2]V. M. Kolybasov, G. A. Leksin, and I. S. Shapiro, Usp. Fiz. Nauk 113, 239 (1974) [Sov. Phys.-Uspekhi 17, 381 (1974)]. I. S. Shapiro, Usp. Fiz. Nauk 92, 549 (1967) [Sov. Phys.-Uspekhi 10, 515 (1968)].