Quasielastic knockout of clusters from atomic nuclei in the theory of multiple scattering

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The use of the Glauber-Sitenko theory leads to new high values of the effective numbers of the d, t, and α clusters in p-shell nuclei.

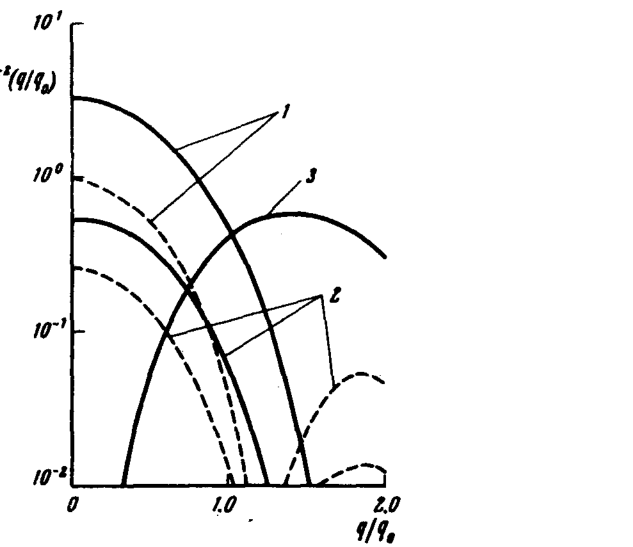
Progress in the theory of multiple scattering[1] allows us to consider the microscopic picture of quasielastic knock out of clusters from atomic nuclei, to modify significantly the old point of view,[2,3] and to make a number of predictions that can be verified experimentally. The amplitude of the quasielastic knock out of a cluster by a high-energy hadron in the region of b-fold scattering is determined by the expression

$$F_{\alpha\beta}(\mathbf{q},\mathbf{p})=\frac{ip_2}{2\pi}(-1)^b\sum_{\gamma\mu}\langle A\alpha|A-b,\beta;\mu;\ b\gamma\rangle\left(\frac{A}{b}\right)^{1/2}$$
$$\times\left(\frac{1}{2\pi i p_1}\right)^b\int d^2\rho\, e^{i\mathbf{p}\rho}\prod_{j=1}^{b}\int d^2p_j\, e^{-\mathbf{p}_j(\vec{\rho}-\vec{\rho}_j)}f(\mathbf{q}_j)|b\gamma\rangle\,\phi_\mu(\mathbf{R})$$
$$\times\exp\{-i\mathbf{QR}\}\Phi_b^*(\mathbf{r})\,d\mathbf{R}\,d\mathbf{r}_1\ldots d\mathbf{r}_b=-\frac{p_2(2\pi i)^{b-1}}{p_1^b}\left[f\left(\frac{\mathbf{p}}{b}\right)\right]^b\sum_{\gamma\mu}$$
$$\times\langle A\alpha|A-b,\beta;\ \mu;\ b\gamma\rangle$$
$$\times\phi_\mu(\mathbf{q})\left(\frac{A}{b}\right)^{1/2}\int dz_1\ldots dz_{b-1}|b\gamma\rangle\,\Phi_b^*(\mathbf{r})\Big|_{\rho_1=\rho_2=\ldots=\rho_{b-1}=0},$$

where $\langle A\alpha|\cdots b\gamma\rangle$ is the fractional-parentage coefficient of shell theory,[3,4] $f(\mathbf{k})$ is the nucleon-nucleon scattering amplitude, $\mathbf{p}_1$ and $\mathbf{p}_2$ are the initial and final momenta of the hadron, $\mathbf{p}=\mathbf{p}_1-\mathbf{p}_2$, and $\phi_\mu(\mathbf{q})$ is the wave function of the mutual motion of the subsystems $(A-b,\ \beta)$ and $(b,\ \gamma)$ in the initial nucleus $(A,\ \alpha)$ (α, β, and γ are the indices of the states). We stipulate $\mathbf{p}_1,\ \mathbf{p}_2\gg\mathbf{p}$ and $\mathbf{p}/b\gg\mathbf{q}$, where $\mathbf{q}$ is the small three-dimensional difference between the almost-two-dimensional momenta $\mathbf{Q}$ and $\mathbf{p}$. As a result, $f(\mathbf{p}/b\pm\mathbf{q})=f(\mathbf{p}/b)$, which leads to the one-dimensional integration $\int dz_i|_{\rho_i=0}$ ($\mathbf{r}_i\equiv\{\rho_i,\ z_i\}$, $\mathbf{r}\equiv\{\mathbf{r}_1,\cdots,\ \mathbf{r}_{b-1}\}$ are the internal Jacobi coordinates of the cluster b), so that the initial and final functions $|b\gamma\rangle$[2,3] and $\Phi_b(\mathbf{r})$[5] can be orthogonal. Owing to the terms with $\gamma\neq 0$ (ns states, $n>0$), the effective numbers $N_{\alpha\beta}^{\text{eff}}(b)$ for $b=d,\ t$, or α and for the knocked-out configuration $(1p)^b$ $(5<A\leq 16)$ in channels with $\mathbf{L}=0$ $(\mathbf{L}=\mathbf{L}_{A,\alpha}-\mathbf{L}_{A-b,\beta})$ acquire high values, three to four times larger than before $(\gamma=0)$.[2,3] For example, curve 1 in the figure corresponds to $N_{0\beta}^{\text{eff}}(d)=7.6$ as against the older 1.9[2] ($N_{\alpha\beta}^{\text{eff}}=\int q^2dq|\Phi_1(\mathbf{q})|^2$). When $\mathbf{L}$ increases to $L_{\max}=b$, the correction decreases to zero (see the figure). The generalization of formula (1) to include the distortions is obvious.

To verify our conclusions we need initial hadron energies 5–10 GeV, so that when they are scattered through a relatively small angle the knocked-out cluster has an energy of several hundred MeV.

The nucleus Li^6, which is of interest for the investigation, has a shell structure only in the $t+\tau$ channel,[3] where our calculated value is $N_{00}^{\text{eff}}(t)\approx 1.5$ as against the older value 0.5.[3] In the $\alpha+d$ channel with non-shell



Form factors for the reaction $O^{16}(p,\,pd)N^{14}$ [curve 3—ground state $1^+(L=2)$, curve 1—1^+ level with $E^*=3.95$ MeV $(L=0)$] and $Li^6(p,\,pt)He^3$ (curve 2). Dashed curves—old theory.[2,3] $q_0=162$ MeV/c for curves 1 and 3 and $q_0=182$ MeV/c for curve 2. The solid and dashed curves 3 coincide.

structure,[3] the increase of $N_{00}^{eff}(d)$ is negligible.

Some similar conclusions were obtained independently by V. V. Balashov and V. N. Meleev.[6]

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