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Scattering of alpha-particles by helium-3 and new resonances of A = 7 system at high excitation energies

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An indication for high-lying states of ^{7}Be at excitation energy E_x 50 MeV was found in the study of ^{6}Li(p,α)^{3}He reaction[1] and it was corroborated for mirror ^{7}Li system by measurement[2] of missing mass spectra in ^{7}Li(h,pd)^{7}Li reaction. Further investigations of high excitation region of A = 7 nuclei are stimulated by the predictions of microscopic theories. The single-channel resonating group method (RGM), which accounts for inelastic channels phenomenologically through introducing an imaginary term to the theoretical interaction potential between A = 3 and A = 4 systems, predicts the cluster-type states with large alpha-particle widths[3]. Filippov and co-workers[4] have taken into account the interplay of cluster and collective modes, and a rich spectrum has been predicted for 1p-shell nuclei at high excitation energies, including E_x above the total break up threshold.

In this work some results are presented on the experimental study of the excitation range 25 to 43 MeV of the ^{7}Be system, which have been obtained through the measurement of the differential cross section $\sigma_0(\theta)$ and analyzing power $A_y(\theta)$ in the elastic scattering of alpha-particles by the unpolarized and polarized ^{3}He target at 56 to 95 MeV energy range.

In comparison with the data[5] at lower energy, the main features of the observed energy dependence of the $\sigma_0(\theta)$ (see Fig. 1) are as follows: the splitting of the maximum at θ = 60° and its almost complete smoothing down with the energy increase; the splitting of another maximum at 120 - 140° with a gradual rearrangement of intensity in this split maximum.

Using the phase shifts resulted from the single-channel RGM [3], we have calculated the $\sigma_0(\theta)$ for the whole studied energy range. The theoretical phase shifts demonstrate the known resonant-like behaviour. At E_x near 30 MeV the δ_4 and δ_5 phase shifts reach, after smooth rise, the maximum values of 90°, and the corresponding absorption coefficients η_L are of minimum values. The energy dependence of G- and H-wave spin-orbit splittings show an obvious structure, and some broad structure is also predicted for L = 6. Since the theoretical angular distributions (Fig.1) reproduce the main features of the experimental data it should be pointed out that the $\sigma_0(\theta)$ data support the conclusion[3] about existence of G- and H-wave resonances at the indicated energy interval.

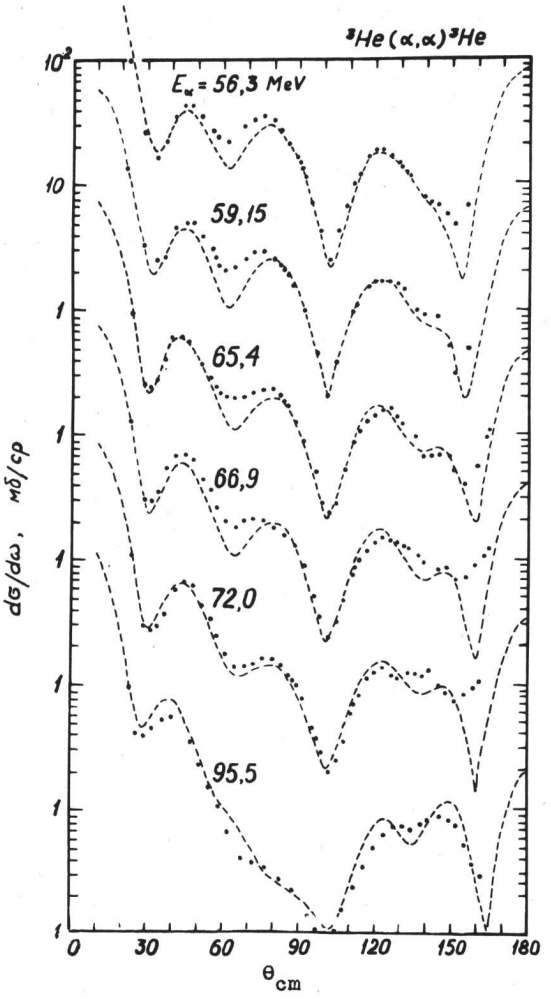

Fig.1. Differential cross sections of the ^{3}He(α,α)^{3}He scattering. The curves are calculated with phase shifts of ref.3.

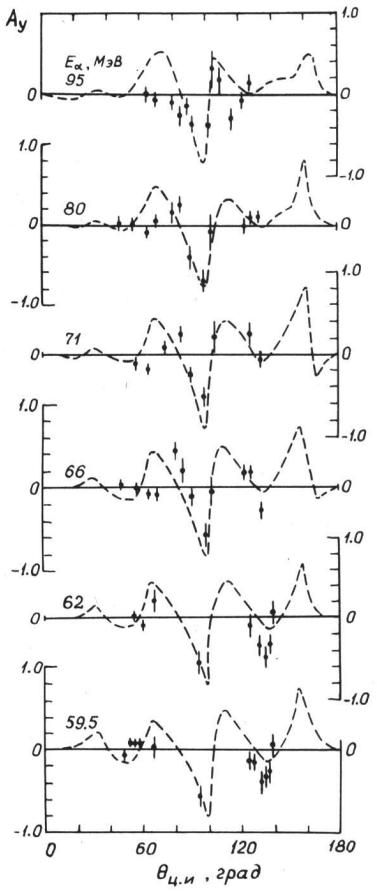

Fig.2. Analyzing power of the $^3He+\alpha$ scattering. See caption to Fig.1.

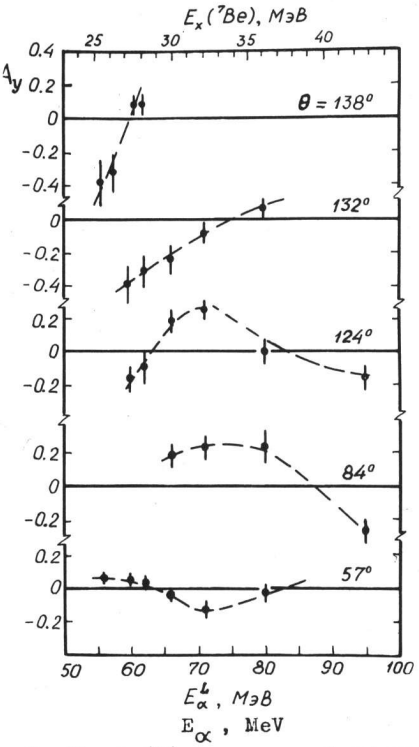

Fig.3. The $A_y(E)$ for several cm angles. The curves are only to guide the eye.

The data for analyzing power are shown in Fig.2. The measurements were performed using the the ^3He polarized target which is described in ref.6. The agreement of measured A_y with the RGM predictions is not as impressive as for $\sigma_o(\theta)$. There are discrepancies in the shape of angular and energy dependence of A_y at θ = 120 - 140° and θ = 60 - 80°. At $\theta \simeq 70°$, $E_{cm} \sim 40$ MeV the predicted by RGM positive maximum of A_y is not observed. The polarization measurements show that some corrections of the theoretical phase shifts are needed.

As it is well known the zero crossing of $A_y(E)$ is one of the essential indications of possible resonance character of interaction. Two zero crossings are observed in the energy dependence of A_y at several angles, see Fig.3, at the excitation energy of 30 and of 38-40 MeV. That supports the prognosis of the microscopic calculations [3,4] on the possibility of unbound states of A = 7 system at E_x of several tens of MeV. More definite conclusions on the properties of the found resonance structure can be drawn only after additional analysis which is in progress.

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