Cluster Structure of the Ground and Excited States of ^{9}Be and ^{10}B Nuclei

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Abstract. Reactions of quasielastic (p, px), (e, ex) knockout and reactions of (γ, x) photodisintegration show that particles x – deuterons, tritons, α-particles and nucleons – escape with a comparable probability out of light nuclei. The significant values of spectroscopic S-factors in these channels are evidence of this. This situation is well interpreted by the wave functions of multiparticle shell model which allows considering from the unified positions both cluster and nucleonic degrees of freedom. The situation in ^{9}Be and ^{10}B nuclei is of peculiar interest. In these nuclei from analysis of symmetry of orbital part of wave functions of states lying at high energies it was suggested for instance in ^{9}Be nucleus to search three-cluster αtd-states in reactions with ^{6,7}Li ions on the same target nuclei. Our calculations showed that in excitation spectra of ^{9}Be nucleus there are three-cluster αtd-states lying in range of both 17-19 MeV and 10-11 MeV. These states have large S-factors in triton, deuteron (and α-particle) channels simultaneously, moreover the last ones appear exactly due to [441] states. Similar conclusions were also obtained for ^{10}B nucleus where three-particle $\alpha\tau$t-levels are connected not only to states with Young [433] scheme, but to [442].

Keywords: Cluster Structure, Multicluster Structure, Spectroscopic Factor, Young Scheme, ^{9}Be, ^{10}B.

1 Multicluster Structure of ^{9}Be Nucleus

A calculation of spectroscopic factors in channels (^{6}Li + t) and (^{7}Li + d) was done, the calculation included in the final state both Young [441] and [432] schemes [1]. In transfer reactions the cross section σ of excitation of levels of final nucleus (in this case ^{9}Be) can be presented by an expression (in assumption of direct mechanism) $\sigma \sim (2J + 1)\Sigma\, S_L \cdot \Phi$, here S_L – corresponding spectroscopic factors and Φ – factor depending on kinematic characteristics. If one considers the quantity Φ to be more or less smooth quantity depending on energy, then the maximums observable in reactions should be connected with maximums of spectroscopic factors.

In figure 1 there are spectroscopic factors in form of histograms including the sums of values of S-factors over energy region of 1 MeV. A comparison with experimental data [2] shows, that the theory describes well the main maximums at energies E = 11.8 MeV, 15.2 MeV, 17.8 MeV and 22 MeV. There are faint peaks at E = 0 and 3 MeV due to Young [441] scheme as well.

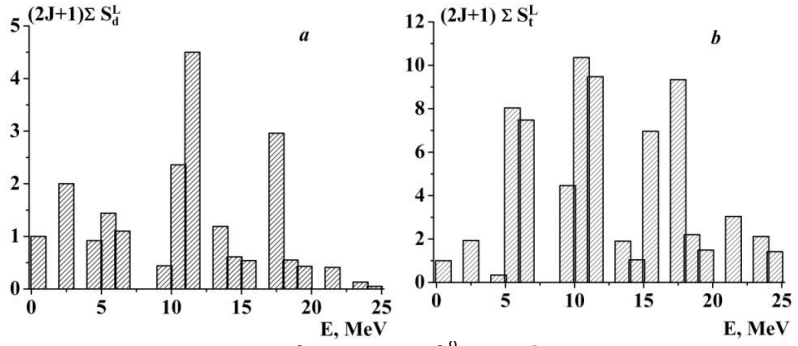

Fig. 1. Spectra of excitation of ^{9}Be nucleus in reactions:
a – ^{7}Li(^{6}Li, α)^{9}Be, b – ^{6}Li(^{7}Li, α)^{9}Be

Thus three-cluster states having αtd-nature can respond to not only orbital Young [432] scheme but with no less weight to Young [441] scheme. That is why there is no surprise in successful description of photonuclear (γ, d) and (γ, t) processes on ^{9}Be nucleus achieved by the authors in ααn-model [3].

Our calculations showed that in spectrum of excitation of ^{9}Be nucleus there are three-cluster αtd-states in region both 17-19 MeV and 10-11 MeV. These states have large S-factors in triton and deuteron channels simultaneously, and the last ones appear due to states [441] exactly. In work [4] the authors analyzed wave functions and suggested searching the three-cluster α*td*-states in reactions with ^{6,7}Li ions on the same target nuclei.

2 Cluster Structure of ^{10}B nucleus

The wave function of ^{10}B nucleus contains in the ground state two components with Young [442] and [433] schemes with contribution of the second one of slightly more than 3% [1].

Because of the smallness of binding energy of nuclei ^{7}Li in (α + t)-channel and ^{6}Li in (α + d)-channel the dominating mechanisms in both ^{6}Li(^{6}Li,d)^{10}B and ^{7}Li(^{7}Li,α)^{10}B cases are the transfer of alpha-particle and triton clusters respectively.

In figure 2 there are values of summarized spectroscopic factors. A comparison with experimental data shows that in whole the theory describes the main maximums observed at energies E = 7, 11 and 13 MeV for joining tritons and at energies E = 7, 11 and 16 MeV for alpha-particles.

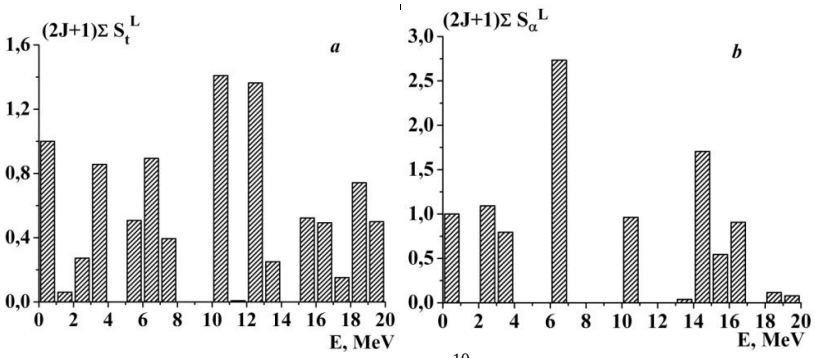

Fig. 2. Spectra of excitation of ^{10}B nucleus in reactions:
a – ^{7}Be + t $\rightarrow$ ^{10}B*, b – ^{6}Li + α $\rightarrow$ ^{10}B*

Conclusion

With aim of study of cluster structure of ^{9}Be and ^{10}B nuclei the reactions of lithium isotopes interaction with each other was considered, such reactions lead to the ground and excited states of ^{9}Be and ^{10}B nuclei. The fact that the main mechanism in reaction with lithium ions is the mechanism of transfer of weakly bound deuterons, tritons and alpha-particle was used. It is turned out that the energy dependence of excitation spectrum is well described by the summarized spectroscopic factors.

For calculations we used the wave functions of multiparticle shell model [1]. For ^{9}Be nucleus the ground state has a strongly pronounced ααn-structure [5]. And αdt-configuration in the ground state practically has no contribution. That is why some calculations for ^{9}Be nucleus on the base of αdt-model are simply mistaken. This is confirmed by the fact that in αdt-model the main transitions with neutron escape out of ^{9}Be nucleus with formation of ^{8}Be nucleus in the ground and the first excited states (with Young [44] scheme) are forbidden, and also the observable alpha-particle escape with formation of ^{5}He nucleus in the ground and the first excited states with Young [41] scheme. For ^{10}B nucleus the analogous calculations give the dominating ααd-structue.

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