Alpha-cluster states in N≠Z nuclei: ^{17}O

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Interest to clustering phenomena in atomic nuclei, especially in light nuclei, has grown steadily over the last few decades. This can be attributed to the realization of the important role that cluster degrees of freedom play in nuclear structure. In addition, the dramatic influence of clustering phenomena on the astrophysically important reaction rates adds urgency to the goal of achieving better understanding of clustering in nuclei. Significant theoretical progress has been achieved in this field. It is no longer necessary to introduce clusters "a priory", instead clustering emerges naturally as a result of microscopic calculations such as AMD [1], FMD [2], Lattice EFT [3], Greens Function Monte Carlo [4], CNCIM [5] and others. Qualitatively all theoretical approaches are in agreement that clustering is an important ingredient in understanding of nuclear structure. The challenge is to achieve quantitative understanding, which is not possible without detailed experimental information on nuclear clusters.

In this report we focus on clustering aspects of nuclear structure in ^{17}O. An interest to this nucleus is twofold. First, the ^{13}C(alpha,n) is an important neutron source reaction for the s-process - the slow neutron capture nucleosynthesis process responsible for the origin of half of all chemical elements heavier than Iron. This reaction proceeds through the population of excited states in ^{17}O and cluster structure has a direct influence on the corresponding reaction cross section. Second, ^{17}O provides a convenient test bench to study an interplay between cluster and single particle degrees of freedom. Its neutron decay threshold is 2 MeV below the alpha decay threshold and therefore nucleon decays can be studied simultaneously with alpha-decays. Also, since cluster structure of ^{16}O is well studied experimentally it becomes possible one can trace the dynamical change in cluster structure due to one extra nucleon. This and also an opportunity to obtain information on the cluster structure of the mirror nucleus ^{17}F using the ^{13}N+alpha reaction are the attractive features of ^{17}O a cluster structure in light nuclei case study.

Here we present data on the α cluster structure in ^{17}O where the lowest nucleon decay is by neutrons and equal to 4.14 MeV, while the α–particle decay threshold is 6.36 MeV. The considerations are mainly based on the results of the very comprehensive ***R*** matrix analysis of the ^{13}C(α, n)^{16}O reaction and the ^{13}C(α, α)^{13}C elastic scattering in the work of Heil et al., [6], and on the new results of the ^{13}C+ α resonance scattering [7] and on the ^{13}C(^{6}Li,d) experiment[8]. We characterized the alpha-cluster properties of the states above the alpha particle decay threshold by $SF=\Gamma_{\alpha\ exp}/\Gamma_{\alpha\ calc}$, where $\Gamma_{\alpha\ calc}$ is the single alpha particle width calculated in the α-core potential. To normalize SFs we calculated these values for the well known states of the alpha-cluster bands in ^{16}O.

Fig.1 shows the distribution of the α cluster strength in ^{17}O in comparison with the known structure in ^{16}O. One can see a very complicated structure in ^{17}O with an alpha-cluster strength shared among several levels with the same spin. It is interesting that only the lowest *l=0, 1, 2* levels in ^{17}O can be easily related with a simple and clear cut classical picture of bands with alternative parities. There is no simple explanation of the drastic change in the structure of the complicated presumably multipartical (alpha-cluster) as a result of extra low bound nucleon.

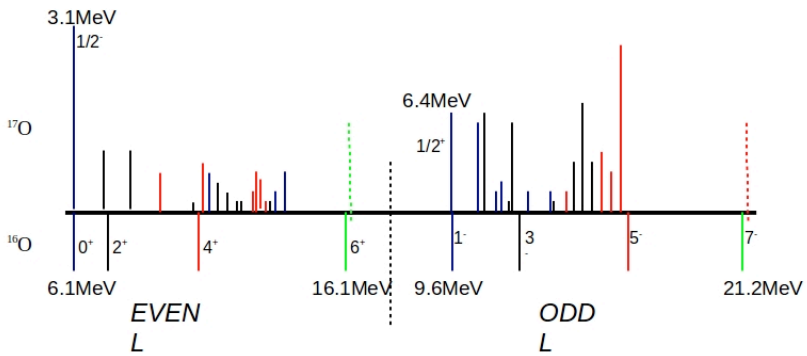

FIG. 1. Alpha-cluster levels in ^{16}O and ^{17}O.

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