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Possible analogs of the Hoyle state in heavier 4N nuclei

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Cluster structure plays an important role in nuclei, in particular, in light ones. One of the common types of clusters is the α-particle. Consisting of four nucleons, the alpha particle is tightly bound and has no excited state up to 20 MeV and behaves as a well-established subunit in nuclei.

Considerable attention has been drawn to the studies of α-cluster states in ^{12}C, especially the second 0^+ state, located at E_x = 7.65 MeV, which is 0.38 MeV above the 3α threshold. This state was named Hoyle state by name of the astrophysicist who predicted it. It plays an extremely important role in nucleosynthesis. The properties of the Hoyle state in ^{12}C determine the ratio of carbon to oxygen formed in the stellar helium burning process that strongly affects the future evolution of stars. A detailed analysis of the structure of ^{12}C with the microscopic 3α cluster model was made about 30 years ago. The 3α generator coordinate method (GCM) and 3α resonating group method (RGM) calculations showed that the Hoyle state in ^{12}C has a loosely coupled 3α structure and an enlarged radius. Modern microscopic calculations in the framework of cluster models such as the antisymmetrized molecular dynamics (AMD) and the fermionic molecular dynamics (FMD) also predict an increased radius of this above-threshold cluster state. Within α-particle Bose-Einstein condensation (αBEC) model the Hoyle state is considered to be the simplest example of the α-condensed state with increased radius.

A question naturally arises: do analogs of the Hoyle state exist in more massive 4N nuclei. First possible candidate is the ^{16}O. αBEC model predicted that 0^+ states, particularly the 4th or the 6th, can be possible analogs of the Hoyle state and have α-condensed structure. Our analysis within Modified diffraction model has shown that 0_2^+-0_6^+ states have normal non-increased radii.

The next goal is ^{20}Ne. The root mean square radii of ^{20}Ne in the short-lived excited states were estimated for the first time from the analysis of α + ^{20}Ne diffraction scattering. Differential cross sections of the elastic and inelastic α + ^{20}Ne scattering in the incident energy range from a few MeV/nucleon up to 100 MeV/nucleon were analyzed by the modified diffraction model. No significant radius enhancement for the members of K^π = 0_1^+ and K^π = 2^- bands in comparison with the ground state was observed. At the same time 20% radius enhancement was obtained for the K^π = 0_1^- band members. Moreover, for the 0_2^+ state located above α-emission threshold increased radius was observed. This result can speak in favor of possible α-condensate structure of the 0_2^+ state and can be considered as a possible analog of the famous 7.65-MeV 0_2^+ Hoyle state of ^{12}C.

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