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ISOMERIC STATES IN HEAVY NUCLEI

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The one- and two-quasiparticle states in heavy nuclei are treated. The change of one-quasiparticle states in isotone chain seems to be rather smooth. Two-quasiparticle states in nuclei of alpha-decay chain of ^{270}Ds are discussed.

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High-spin K-isomer states, which are usually assumed as two-quasiparticle high-spin states, were observed in heavy nuclei ^{250,256}Fm, ^{252,254}No, ^{266}Hs, and ^{270}Ds [1]. The one-quasiparticle isomeric states are also known among odd heaviest nuclei. In order to calculate the energies of isomeric states, the two-center shell model [2] is used for finding the single-particle levels at the ground state of nucleus. The shape parameterization used in this model effectively includes all even multipolarities. The dependence of the parameters of $\mathbf{ls}$ and l^2 terms on A and N–Z is modified for the correct description of the ground state spins of known odd actinides. In order to substantiate our calculations based on the parameterization of nuclear shape in the two-center shell model, the results should be compared with the results obtained with other approaches.

The contribution of an odd nucleon, occupying a single-particle state $|\mu\rangle$ with energy e_μ, to energy of a nucleus is described by the one-quasiparticle energy $\sqrt{(e_\mu - e_F)^2 + \Delta^2}$. Here, the Fermi energy e_F and the pairing-energy gap parameter Δ are calculated with the BCS approximation. The values of Δ obtained in our calculations differ from those in [3, 4] within 0.05–0.1 MeV.

The microscopic corrections, quadrupole parameters of deformation calculated with the two-center shell model are close to those obtained with the microscopic–macroscopic approaches in [3, 4]. The ground state of ^{248}Fm is found to be at $\beta_2 = 0.25$ and $\beta_4 = 0.027$. For comparison, in [4] $\beta_2 = 0.235$ and $\beta_4 = 0.049$ in this nucleus. While in ^{247,248,249}Fm the microscopic corrections in [4] are -3.52, -3.57, and -3.97 MeV, respectively, we get -3.85, -3.88, and -4.3 MeV.

To demonstrate the quality of our calculations with the two-center shell model, the calculated energies of one-quasineutron states for ^{245}Cm are compared in Fig. 1 with the experimental data [5]. The discrepancy in energy does not exceed 300 keV that is quite satisfactory. The Nilsson (asymptotic) quantum numbers $[Nn_z\Lambda]$ are assigned to each state. In addition, we calculated the one-quasiparticle states with the quasiparticle–phonon model (QPM) [6] (Fig. 1) and Hartree–Bogoliubov approach with indicated Skyrme forces [7] (Fig. 2). One can see that all approaches provide the similar quality of the description of the experimental data. Therefore, the results obtained with the two-center shell model seem to be well confident. The energies of one-quasiparticle states change rather smoothly in the isotone chain (Figs. 3–5). Therefore, the revealing of isomeric state in one of the nucleus of isotone chain indicates the presence of the same isomeric state in neighboring isotones.

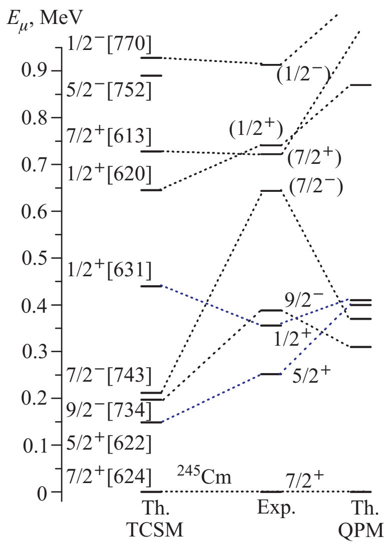

Fig. 1. The calculated energies of one-quasiparticle states of ^{245}Cm are compared with the experimental data [5]. The calculations are performed with the two-center shell model (TCSM) and with the quasiparticle–phonon model (QPM)

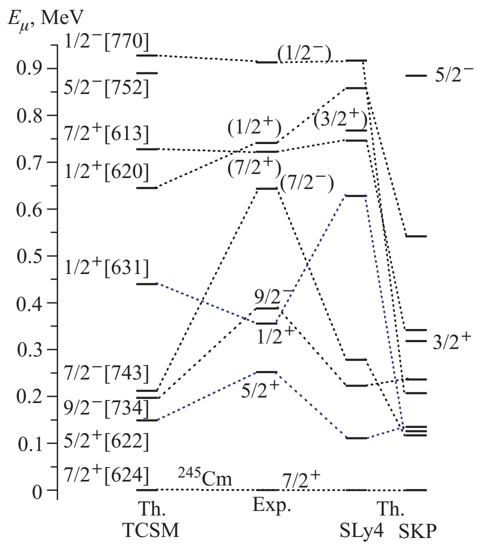

Fig. 2. The same as in Fig. 1, but the calculations are also performed with the Hartree–Bogoliubov approach with the indicated interactions (SLy4 and SKP)

For ^{270}Ds, ^{266}Hs, ^{262}Sg, ^{258}Rf, and ^{254}No, the calculated values of Q_α for the ground state to ground-state α decays are compared with the available experimental assignments [5, 8, 9] in Fig. 6 where the lowest two-quasiparticle

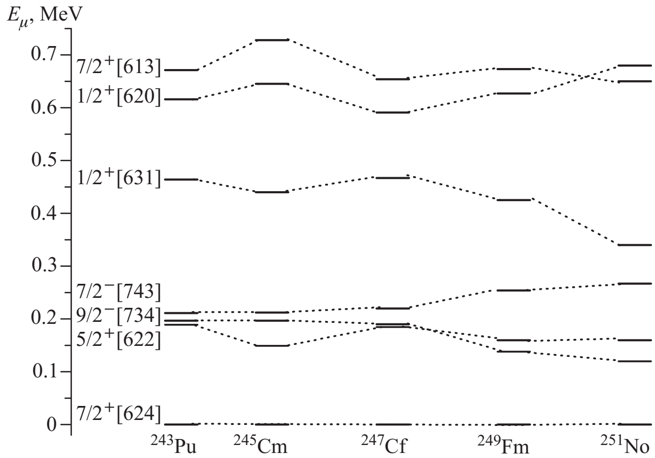

Fig. 3. The one-quasiparticle states in $N = 149$ nuclei calculated with the two-center shell model

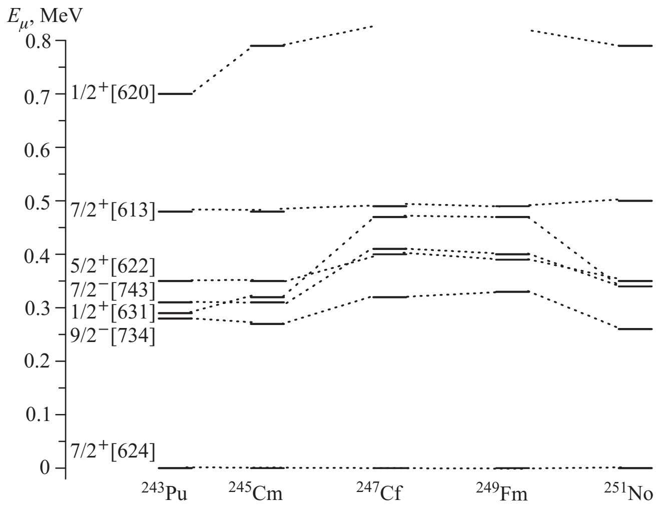

Fig. 4. The one-quasiparticle states in $N = 149$ nuclei calculated with the quasiparticle–phonon model

states are shown. We underestimate the Q_α value for ^{266}Hs like in [4, 10] resulting in $Q_\alpha = 9.69$ and 10.04 MeV, respectively. While we overestimate the value of Q_α for ^{254}No, [4, 10] underestimate it. Therefore, our description of Q_α seems to be satisfactory. There are lowest two-quasineutron isomeric

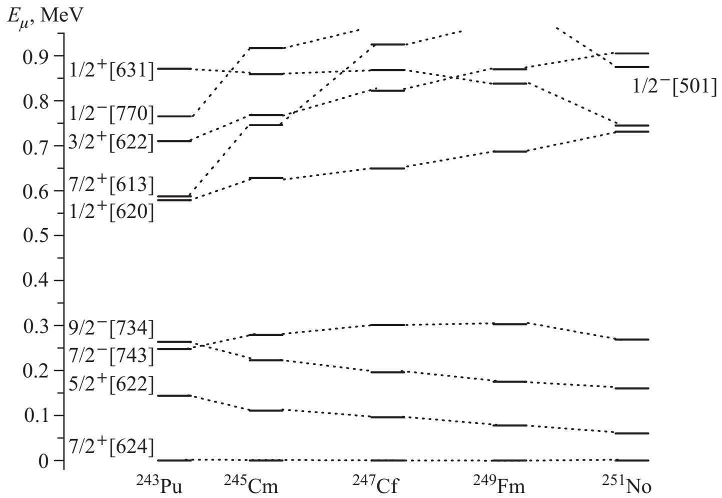

Fig. 5. The one-quasiparticle states in $N = 149$ nuclei calculated with the Hartree–Bogoliubov approach using the SLy4 interactions

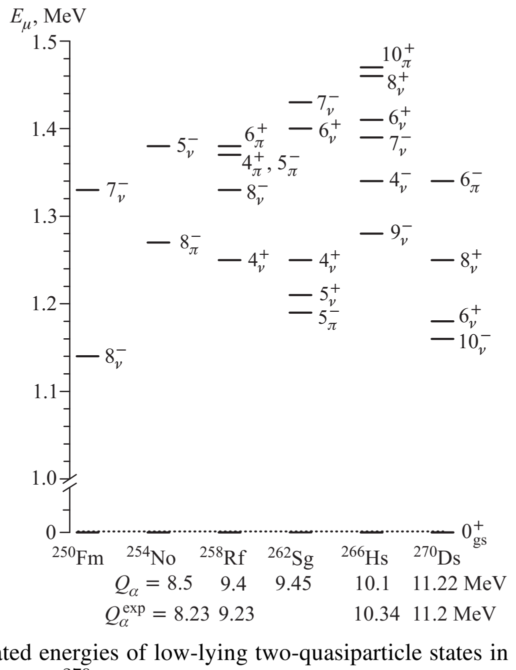

Fig. 6. The calculated energies of low-lying two-quasiparticle states in the indicated nuclei of the α-decay chain of ^{270}Ds. The calculated values of Q_α are compared with available experimental data [5, 8, 9]

states $10^-_\nu(11/2^-[725] \otimes 9/2^+[604])$ and $6^+_\nu(11/2^-[725] \otimes 1/2^-[761])$ in ^{270}Ds. One can expect the γ transitions from these isomeric states to the ground state with subsequent α decays. The event number 2 in [8] can be attributed to this possibility and also to the α decay from $0^+_{\rm gs}$ state of ^{270}Ds to $2^+_{\rm gs}$ state of ^{266}Hs.

Analyzing the possible α decays from the isomers 10^-_ν and 6^+_ν in ^{270}Ds, we propose that the most probable α decays occur either to the 10^- states of $K^\pi = 1^-$ band or to the states 2^+, 4^+, and 6^+ of the ground-state rotational band of ^{266}Hs. The energies of rotational states are estimated as in [11]. These α decays can be related to the event numbers 7 and 8 in [8] since they correspond to similar Q_α and T_α. For the reliable check of the calculated results the experiment with better statistics is desirable.

Concluding, the presented microscopic methods are suitable to describe structure properties of heaviest nuclei and to predict the energies of K-isomer states. If the K-isomer state would be revealed in one heavy nucleus, one can find the same state in neighboring isotones. One can expect the α decays via the isomeric states. Note that the calculated values of Q_α and, correspondingly, the estimated values of α-decay half-lives seem to be in a satisfactory agreement with the experimental data.

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