GROUND-STATE ROTATIONAL ENERGIES OF DEFORMED SUPERHEAVY NUCLEI* **

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Ground-state rotational energies of heavy and superheavy nuclei are calculated in the cranking approximation. Even-even nuclei with proton number $Z = 94 - 114$ and neutron number $N = 146 - 168$ are considered. The results are interpreted in terms of the shell structure of these nuclei.

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1. Introduction

There is an impressive progress both in synthesis and in study of the properties of superheavy nuclei. Nuclei with proton numbers Z, up to $Z = 112$, and with neutron numbers N, up to $N = 163$, have been studied experimentally. This progress has been discussed in [1]. Recently, an evidence for the observation of an even heavier nucleus, $^{283}112$, has been presented [2]. According to theory, these nuclei exist only due to shell effects [3] and they are deformed. Due to this, they are called "deformed" superheavy nuclei. There is, however, no direct experimental evidence for their deformed shapes. The heaviest nucleus for which such an evidence has been obtained (by observation of a ground-state rotational band) is the nucleus ^{254}No [4].

The objective of this paper is to calculate the ground-state rotational energies of heavy and superheavy nuclei, to see the systematics expected for these energies. In particular, to see how much the strong shell effects, already seen in the half-lives of these nuclei, are reflected in this systematics.

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2. Description of the calculations

Energy (mass) of nucleus is calculated within a macroscopic-microscopic approach. The macroscopic part of the energy is described by the Yukawa-plus-exponential model, while the microscopic part is the Strutinski shell correction, based on the Woods-Saxon single-particle potential.

Equilibrium deformation of a nucleus is calculated by minimization of its energy in the 4-dimensional deformation space $\{\beta_\lambda\}$, $\lambda = 2, 4, 6, 8$, where β_λ are the usual deformation parameters. The calculations are very similar to those of [6], with the only difference that a slightly larger strength of the pairing interaction is used in the present paper. The strength is assumed in a rather usual form (*e.g.* [5])

$$A \cdot G_l = g_{0l} + g_{1l} I, \tag{1}$$

where A is the mass number and $I = (N - Z)/A$ is the relative neutron excess of a nucleus. The parameters g_{0l} and g_{1l} are taken as those of the paper [5], where they have been fitted to experimental odd-even mass differences of heavy nuclei, but renormalized by one factor, the same for all four parameters. This factor has been fitted to known (experimental) values of the energy E_{2+} of heavy nuclei. This procedure may be considered as a correction of the previous fit to odd-even mass differences, as these differences include other effects (*e.g.* shell effects), in addition to the pairing effects. The result is

$$\begin{array}{lll} g_{0\mathrm{n}} = 20.82\ \mathrm{MeV}, & g_{1\mathrm{n}} = -22.4\ \mathrm{MeV} & for\ \ l = \mathrm{n}\ \ (\mathrm{neutrons}), \\ g_{0\mathrm{p}} = 18.85\ \mathrm{MeV}, & g_{1\mathrm{p}} = +27.3\ \mathrm{MeV} & for\ \ l = \mathrm{p}\ \ (\mathrm{protons}). \end{array} \tag{2}$$

Thus, the renormalization factor, with respect to the values obtained in [5] (and also used in [6]) is 1.0485.

3. Results and discussion

To specify the energies of an ideal rotational band, it is enough to give the energy of any state of the band. For even-even nucleus, this may be *e.g.* the first rotational state: 2+. To obtain this energy, we calculate the moment of inertia of the nuclei. As we are interested in the ground-state rotational bands, we analyze the ground-state moments of inertia. This quantity is calculated in almost the same way as used and described *e.g.* in [7–9], the differences concerning only some details of the calculations. For example, we use the Woods–Saxon single-particle potential, instead of the Nilsson potential taken in those papers. The results obtained for the energy of the first rotational 2+ state, E_{2+}, are shown in Fig. 1.

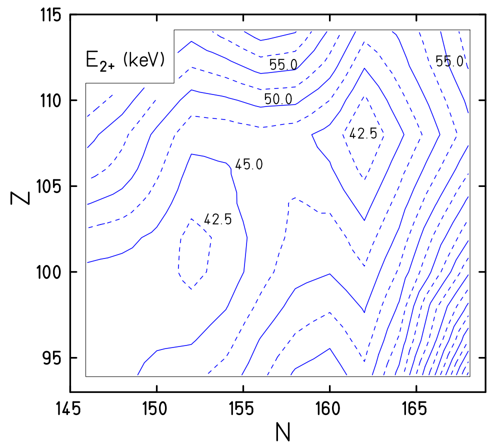

Fig. 1. Contour map of calulated energy E_{2+} of the first rotational state 2+.

One can see in Fig. 1 that two minima of E_{2+} are obtained for the considered nuclei. One of them (41.7 keV) is obtained for the nucleus ^{254}No, and the other (40.0 keV) for ^{270}Hs. These two minima should be connected with the two local maxima of the shell correction to energy (in their absolute values) obtained for nuclei around ^{254}No and ^{270}Hs, as discussed *e.g.* in [5]. A maximum of the shell correction corresponds to a large energy gap in the single-particle spectrum, which results in a weak pairing correlation. The latter is directly illustrated in Fig. 2 for neutrons, where a map of the pairing-energy gap $\Delta_{\rm n}$ is shown.

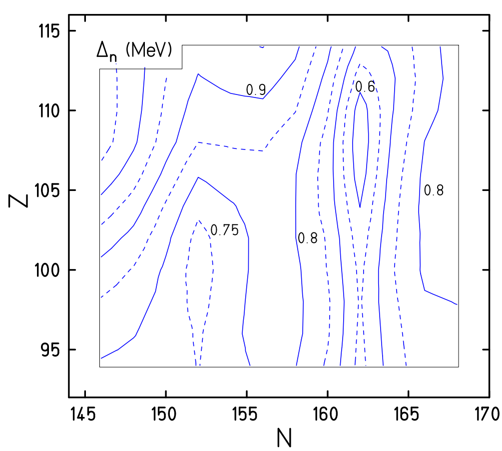

Fig. 2. Contour map of the neutron pairing-energy gap $\Delta_{\rm n}$.

One can see in Fig. 2 that clear minima of $\Delta_{\rm n}$ are obtained for the neutron shell closures at $N = 152$ and 162. As small pairing correlations correspond to large values of the moment of inertia of a nucleus (*cf. e.g.* [8]), these two minima of $\Delta_{\rm n}$ result in the two minima of the rotational energy E_{2+}. Thus, we interpret the two minima of E_{2+}, shown in Fig. 1, as due to the largest shell corrections to energy, which, in considered region of nuclei, are obtained for ^{254}No and ^{270}Hs.

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