SURFACE DIFFUSENESS AND PROPERTIES OF SPHERICAL SUPERHEAVY NUCLEI* **

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Proton and neutron surface diffusenesses are treated as degrees of freedom in macroscopic-microscopic calculations. Their values are established by minimization of the energy of a nucleus. The effect on nuclear properties such as single-particle spectra and the shell correction to the energy (mass) of a nucleus is studied. Even-even spherical superheavy nuclei with the magic neutron number $N = 184$ and the proton numbers $Z = 110$ to 126 are considered.

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1. Introduction

In a macroscopic-microscopic description of nuclei, the diffuseness of the nuclear surface is usually treated as independent of the nucleus. In particular, this is the case in the studies of the properties of superheavy nuclei (*e.g.* [1,2]). We know, however, that this quantity changes from one nucleus to another (*e.g.* [3]). It seems then to be reasonable not to fix the value of this quantity, but to treat it as a degree of freedom with its final value obtained by minimization of the nuclear energy, as is done for the deformation degrees of freedom. Such a procedure has been recently adopted in a macroscopic description of a nucleus [4].

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The objective of this paper is to extend this procedure to a full macroscopic-microscopic model and to estimate its effect on the properties of superheavy nuclei. Properties such as single-particle energy levels and the shell correction to the nuclear energy are considered. Spherical superheavy nuclei with the closed neutron shell at the neutron number $N = 184$ are analyzed.

2. Description of the calculations

The macroscopic part of the diffuseness-dependent energy is described by the Thomas–Fermi model [4]. The microscopic part is the Strutinski shell correction based on the Woods–Saxon single-particle potential.

In both parts of the energy, the diffusenesses of the neutrons as well as the protons are treated as variable degrees of freedom. Their equilibrium values are found by minimization of the total (macroscopic-microscopic) energy of a nucleus.

3. Results

Figure 1 shows the dependence of the proton single-particle energies e_{p} on the surface diffuseness z of the Woods–Saxon potential for protons, calculated for the nucleus $^{310}126$. For each value of z, the radius of the proton potential is chosen so that the number of protons ($Z = 126$), contained in the potential up to the Fermi surface, is kept constant. (The proton density distribution is calculated in the Thomas–Fermi approximation.)

One can see in Fig. 1 that the shell structure of a nucleus depends strongly on z. In particular, the energy gap at $Z = 114$ decreases, while the gap at $Z = 126$ increases with increasing z. For purposes of illustration, Fig. 1 is plotted for a large range of z. In reality, the equilibrium value of z, obtained for protons in the nucleus $^{310}126$ is $z_{\mathrm{eq}} = 0.78$ fm, i.e. it is only about 12% larger than the value $z_0 = 0.70$ fm, used by us in earlier calculations (*e.g.* [1,2]). This increase of z does not change the gap at $Z = 114$, while it increases the gap at $Z = 126$ by about a factor of three.

Figure 2 shows the shell correction, E_{sh}, to the ground-state energy, calculated for 9 even-even nuclei with the magic neutron number $N = 184$. According to the calculations, these nuclei are spherical. The calculations were done twice: first, when the surface diffusenesses are treated as degrees of freedom (TF) and, second, when they are fixed (Y).

One can see in Fig. 2 that in the former case the shell correction energy is increased (in absolute value) in comparison to the latter one. This increases the nuclear stability, especially for heavier elements. The shell correction is only a little larger for the nucleus $^{298}114$, while it is larger by more than 2 MeV for the nucleus $^{310}126$, as compared to the case of fixed diffusenesses.

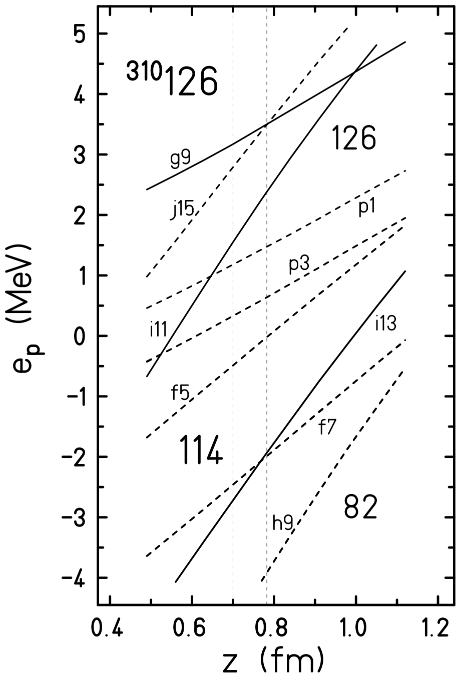

Fig. 1. Proton single-particle energies calculated as functions of the surface diffuseness z of the Woods–Saxon potential for protons, for the nucleus $^{310}126$. Spectroscopic symbol corresponding to the orbital angular momentum l and total spin (multiplied by two) $2j$ are given for each energy level. Energy levels with odd parity are denoted by dashed lines. Thin dashed vertical lines correspond to $z_0 = 0.70$ fm (characteristic of our previous calculations) and the equilibrium value $z_{\rm eq} = 0.78$ fm, obtained as an optimum for the nucleus $^{310}126$.

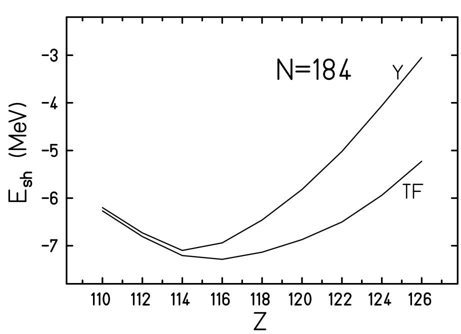

Fig. 2. Shell correction energy, $E_{\rm sh}$, calculated when the surface diffusenesses are treated as degrees of freedom (TF) and when they are fixed (Y).

The complete result for the nucleus ${}^{310}126$ is as follows: z_{eq} increased by 12% for protons and 4% for neutrons, the shell correction increased (in absolute value) by 2.18 MeV and the macroscopic energy (also in absolute value) by 2.34 MeV. Thus, the total binding energy of this nucleus is increased by 4.52 MeV with respect to the case when the diffusenesses z are fixed at the value $z_0 = 0.70$ fm.

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