ON THE FISSION HALF–LIVES OF SPHERICAL SUPERHEAVY NUCLEI* **

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(Received December 10, 1996)

Spontaneous fission of spherical superheavy nuclei is studied in a multidimensional deformation space. Potential energy, fission barrier and fission half-life are analyzed. The half-life is studied in a dynamical approach. Even–even isotopes of the element 114, with neutron number $N = 174-186$, are considered. Alpha-decay half-lives are also given, for completeness.

PACS numbers: 25.85.Ca, 21.10. Tg, 24.75. +i, 27.90. +b

1. Introduction

An analysis of the experimental half–lives $T_{\rm sf}$ of deformed heaviest nuclei has shown that these half–lives are rather well reproduced by dynamical calculations, performed in a multidimensional deformation space [1]. The objective of the present paper is to perform similar calculations for spherical superheavy nuclei. The half–lives $T_{\rm sf}$ of these nuclei have been calculated earlier in a multidimensional deformation space [2], but only in a more approximate, statical way.

For our analysis, we choose nuclei of the element 114, which are expected to have the longest $T_{\rm sf}$, among the spherical superheavy nuclei [2]. Even–even isotopes with neutron number $N = 174 - 186$ are considered.

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* Presented at the XXXI Zakopane School of Physics, Zakopane, Poland, September 3–11, 1996.

** Work supported by the Polish Committee for Scientific Research (KBN), grant no. 2 P03B 156 08.

† On leave of absence from the Institute for Atomic Physics, Bucharest, Romania.

2. Theoretical model

The potential energy of a nucleus is calculated in a macroscopic–microscopic approach. The Yukawa–plus–exponential model [3] is taken for the macroscopic part of the energy, and the Strutinski shell correction, based on the Woods–Saxon single–particle potential [4], is used for the microscopic part. The residual pairing interaction is treated in the usual BCS approximation. The strength of the interaction is taken the same as in [5], where it has been fitted to recent data for nuclear masses. The spontaneous–fission half–life $T_{\rm sf}$ is calculated in the dynamical way (*e.g.* [6, 1]). It consists of the search for a one–dimensional fission trajectory in a multidimensional deformation space which minimizes the action integral corresponding to the penetration of the fission barrier by a nucleus. The inertia tensor is calculated in the cranking approximation.

The calculations are performed in the 3–dimensional deformation space $\{\beta_\lambda\}$, where β_λ are the usual deformation parameters and λ=2,4,6. Thus, the axial symmetry of a fissioning nucleus is assumed. According to the studies [2, 7], the non–axiality degree of freedom may significantly modify the static fission barrier, but it leaves the dynamical barrier almost unchanged.

Concerning the details of the calculations, we use the single–particle energies and wave functions of one ("basic") nucleus, $^{294}114_{180}$, to calculate the fission properties of all other isotopes with $N = 174 - 186$. According to the study [2], this approximation is rather good for nuclei which are not too far from the "basic" nucleus. The potential energy and the inertia tensor are calculated in the following grid points: $\beta_2 = 0(0.05)0.85$, $\beta_4 = -0.15(0.05)0.25$, $\beta_6 = -0.18(0.06)0.12$. Then, both these quantities are interpolated (by the standard procedure SPLIN3 of the IMSL library) to a more dense grid with the steps: $\Delta\beta_2 = 0.025$, $\Delta\beta_4 = 0.01$, $\Delta\beta_6 = 0.01$. Only on such a dense grid has the variational calculation been performed, to find the dynamical fission trajectory and to calculate the action integral along it, using the dynamical–programming method described in [6]. Similarly as in [1], the zero–point energy in the fission degree of freedom is taken as $E_{\rm zp} = 0.7$ MeV.

3. Results and discussion

3.1. Potential energy surface and fission barriers

Figure 1 gives a map of the potential energy E calculated for our "basic" nucleus $^{294}114$. At each point (β_2, β_4), the energy is minimized in the β_6 degree of freedom. The dynamical fission trajectory $L_{\rm dyn}$, along which the action integral is minimal, is shown. One can see that it has a tendency to be close to a straight line and to have a possibly small slope with respect to the β_2-axis, as both these features lead to a small effective inertia and, consequently, to a small action integral, along this trajectory.

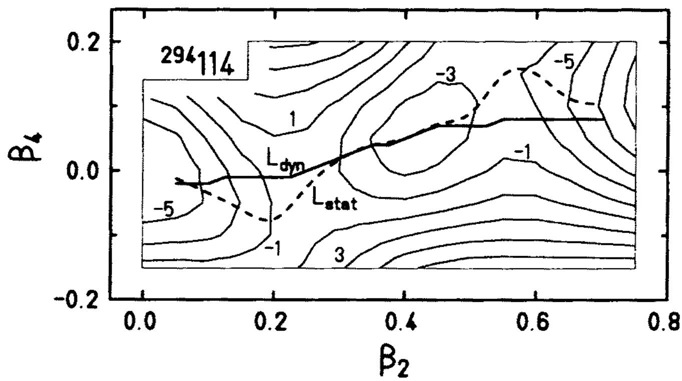

Fig. 1. Contour map of the potential energy E calculated as a function of the deformations β_2 and β_4, for the nucleus $^{294}114$. Numbers at the contour lines give the values of the energy. Dynamical (solid line), $L_{\rm dyn}$, and statical (dashed line), $L_{\rm stat}$, fission trajectories are shown.

The static trajectory $L_{\rm stat}$ is also shown in Fig. 1, for comparison. This trajectory corresponds to minimal potential energy for a given deformation β_2. The effective inertia is large along this trajectory, resulting in a larger action integral than along the dynamical trajectory.

The respective dynamical and statical fission barriers, *i.e.* the potential energies E calculated along the dynamical and statical fission trajectories, are rather thin. They end at a deformation $\beta_2 \approx 0.7$. They are, however, rather high, due to a large shell correction to the potential energy at the equilibrium point, $\beta_\lambda^0 = 0$, of the nucleus $^{294}114$. The correction is: $E_{\rm sh} = -7.1$ MeV. The dynamical barrier is by about 0.6 MeV higher than the statical one and has a somewhat different shape.

3.2. Fission half-life

The fission half-lives of the element 114 are shown in Fig. 2. The α-decay half-lives T_α, calculated in [8], are also given, for completeness. One can see that the largest $T_{\rm sf}$, of the order of 10^7 years, is obtained for the isotope $^{298}114$ ($N = 184$). The half-life decreases very fast with N increasing

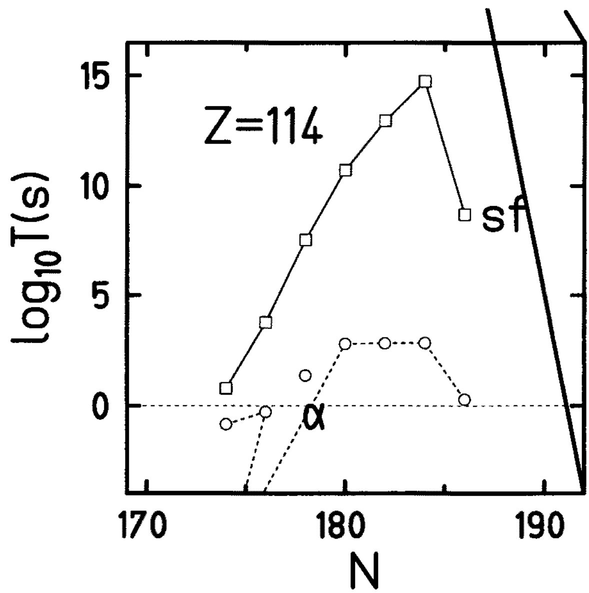

Fig. 2. Logarithm of the spontaneous-fission half-lives (sf), given in seconds, calculated as a function of the neutron number N, for the element 114. The α-decay half-lives (α) [8] are also given, for completeness.

above the value $N = 184$. For all considered isotopes, the α-decay half-life T_α is smaller than $T_{\rm sf}$: $T_\alpha < T_{\rm sf}$. Due to this, the longest total half-life, equal to T_α and obtained for $^{298}114$ ($N = 184$), is much shorter than $T_{\rm sf}$ and is equal to about 11 min.

The authors would like to thank J. Skalski and R. Smolańczuk for testing some of the results and for useful discussions. They would also like to thank P. Armbruster, S. Hofmann, G. Münzenberg, W. Nörenberg, Yu.Ts. Oganessian, A.G. Popeko and A.V. Yeremin for helpful conversations. One of us (R.A.G.) is grateful to the Soltan Institute for Nuclear Studies, Warsaw, for a postdoctoral appointment at the Theory Department of this Institute and for a warm hospitality extended to him, as well as to the Polish Committee for Scientific Research (KBN) for support.

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