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SINGLE-PARTICLE POTENTIALS AND THE STABILITY OF SUPERHEAVY NUCLEI

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Recently, it has been shown that a rather wide region of superheavy spherical nuclei appears to exist with a fission barrier different from zero/1-3/. This barrier is caused wholly by the influence of shell effects on the nuclear deformation energy. The calculations of fission barriers were performed /1-3/ employing the Strutinsky method/4/, where the scheme of single-particle levels is applied to the calculation of the shell correction for the liquid drop energy of the nucleus.

The present paper is aimed at study of the influence of single-particle potential parameters on the calculation results of fission barrier for superheavy nuclei.

Nowadays there are several sets of the Woods-Saxon potential parameters available, obtained by treating the spectroscopic data for nuclei close to ^{208}Pb . In this paper we use the parameters of Rost/5/, Nemirovsky and Chepurnov /6/, Blomquist and Wahlborn/7/. The parameter values for the ^{298}114 nucleus are given in Table 1. The levels for the Woods-Saxon deformed potential were obtained in the first order of the perturbation theory .

Besides, calculations were performed with Nilsson level scheme which corresponds to parameters μ and κ equals:/8/

for protons $\mu = 0.70$, $\kappa = 0.0517$

for neutrons $\mu = 0.23$, $\kappa = 0.0633$.

In all cases investigated the conclusion about the existence of the superheavy nuclei region with the relative stability against spontaneous fission appears to be correct. However, the values of the fission barrier height for nuclei under investigation depend considerably upon the shell-model potential parameters. Table 2 presents values of the fission barrier height for some nuclei obtained with various schemes of single-particle levels. These results refute Rost's conclusion about the non-stability of nuclei against spontaneous fission in the considered region/4/. This provides evidence that the nuclear stability cannot be judged reliably by the size of the gap in the single-particle spectrum.

The obtained values of the fission barrier height allow one to suggest some reactions in which nuclei with relatively long half lives against fission may be produced:

$$^{238}U + {}^{68}Zn \rightarrow {}^{302}122 + 4n$$

$$^{242}Pu + {}^{66}Zn \rightarrow {}^{304}124 + 4n$$

$$^{242}Pu + {}^{68}Zn \rightarrow {}^{306}124 + 4n$$

$$^{244}Pu + {}^{68}Zn \rightarrow {}^{308}124 + 4n$$

$$^{248}Cm + {}^{66}Zn \rightarrow {}^{310}126 + 4n \,.$$

It should be noted that all these nuclei are far off the beta stability line and may undergo the alpha decay. However, at the motion along the beta decay chain the stability against spontaneous fission will increase. In the case of the alpha decay even after the three alpha particle emission nuclei will have a sufficiently high fission barrier. Therefore it can be hoped that alpha and beta decays will not prevent the reactions mentioned from the successful realization. However these might complicate the identification of the superheavy nuclei produced.

Note in conclusion that such a strong dependence of fission barrier calculation results on the single-particle potential parameters does not allow one to perform reliable estimates of spontaneous fission half lives for superheavy nuclei.

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Table 1

Single-particle potential parameters for the $^{298}114$ nucleus

	protons					neutrons				
	a (fm)	r_o (fm)	λ	V_o (MeV)	r_{so} (fm)	a (fm)	r_o (fm)	λ	V_o (MeV)	r_{so} (fm)
1. Rost	0.7	1.275	17.8	60.5	0.932	0.7	1.347	31.5	40.6	1.28
2. Nemirovsky and Chepurnov	0.631	1.24	35	61.2	1.24	0.631	1.24	35	45.4	1.24
3. Blomquist and Wahlborn	0.67	1.279	32	58.6	1.279	0.67	1.279	32	45	1.279

Table 2

Fission barrier height values in MeV obtained with various level schemes

Level scheme Nucleus	$^{288}114$	$^{298}114$	$^{294}118$	$^{298}120$	$^{302}122$	$^{304}124$	$^{306}124$	$^{308}124$	$^{310}126$
1. Rost	4	10	8	10	12	12	13	14	13
2. Nemirovsky & Chepurnov	8	12	9	9	8.5	7	8	9	8
3. Blomquist & Wahlborn	4	10	6.5	7	7.5	7	7.5	8	7
4. Nilsson	4.5	10	5.5	6	7	6	7	8	7