Superdeformed Ground State of Superheavy Nuclei

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1. Introduction

One very successful theoretical approach is with self-consistent mean-field models, perhaps the leading theory for describing and predicting properties of heavy nuclei. For a long time it was believed that the existence of superheavy nuclei is due to their spherical shell structure. However, it is known experimentally that the heavy nuclei of the actinum series are well deformed, this fact strongly suggests that deformed configurations are as important as the spherical one for stability of superheavy nuclei. It has been found in recent relativistic mean field (RMF) calculations that many superheavy nuclei may have superdeformed ground state [1, 2]. In other words, the second minimum of the potential (at the quadrapole deformation β_2) is obtained to be lower than the first one for these nuclei. It has also been found that alpha decay half-lives T_α are quite long, indicating a chance for the observation of these nuclei, alongwith their quite high fission barrier, suggesting that the spontaneous-fission half-lives T_{sf} may be even longer than T_α.

If these results are realistic, they will substantially change our view of superheavy nuclei, not only of their structure and properties, but also of the probability of their synthesis. In this study we put emphasis on the role of deformation on the structure of superheavy ncueli. We will be presenting the results for the potential energy surfaces (PES) studies for the superheavy nucleus $^{292}120$ and $^{288}118$ by using relativistic mean-filed (RMF) and non-relativistic Skyrme Hartree-Fock (SHF) model in a constrained calculations.

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TABLE I: The Q_α and $log_{10}T^{\alpha}_{1/2}$ (in sec) for $^{292}120$ and $^{288}118$ nucleus.

A	Z	Formalism	BE	β_2	Q_α	log_{10} ($T^{\alpha}_{1/2}$)
292	120	RMF(NL3*)	2060.87	0.55	11.67	-2.36
		RMF(NL3)	2064.11	0.54	10.62	0.4
			2063.38	0.00	10.85	-0.23
		SHF(SKI4)	2047.68	0.11	12.54	-4.27
			2047.27	0.53	13.42	-6.07
		SHF(SLy4)	2028.71	0.11	13.01	-5.65
			2026.75	0.55	13.03	-5.26
		FRDM	2055.19	-0.13	13.89	-6.96
		Sobiczewski				
288	118	RMF(NL3*)	2044.27	0.55	12.41	-4.52
		RMF(NL3)	2046.43	0.54	12.40	-4.51
			2045.93	-0.01	11.63	-2.77
		SHF(SKI4)	2032.39	0.14	12.76	-5.27
			2031.92	0.55	11.61	-2.74
		SHF(SLy4)	2013.43	0.15	12.82	-5.39
			2011.47	0.54	12.47	-4.66
		FRDM	2040.79	0.08	12.87	-5.5
		Sobiczewski				

2. Method of the calculations and Discussions

In our calculation both the non-relativistic Skyrme-Hartree-Fock SHF [3] and the deformed Relativistic Mean Field RMF [4] codes in harmonic bases are used. The RMF calculations reported here include the axially symmetric deformation of the supereavy nuclei wherein the pairing forces are treated using the BCS theory [5]. We have used the improved version of NL3 parameter set (NL3*), standard NL3, SkI4 and SLy4 parameter sets for our calculations.

We describe here some results calculated using nonrelativistic SHF model in a constrained calculations [6] in order to show the enrgy surface of some superheavy nuclei. From the figure it is clear that the minima and maxima

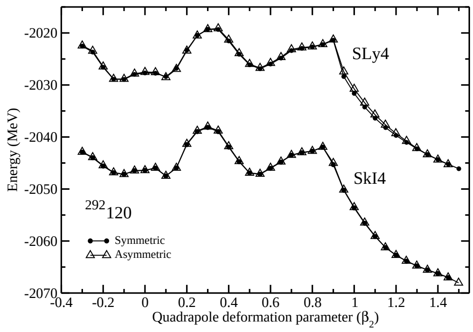

FIG. 1: The energy surface of the nucleus ^{292}120 obtained by a constrained nonrelativistic calcula-tio

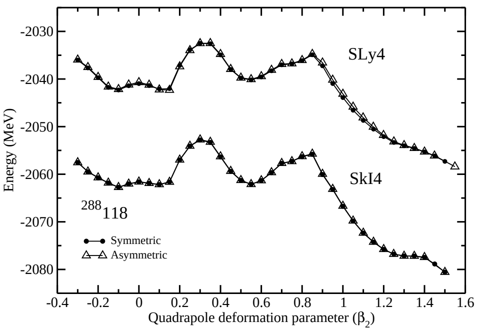

FIG. 2: The energy surface of the nucleus ^{288}118 obtained by a constrained nonrelativistic calculations.

in both the SHF (SkI4) and SHF (SLy4) parameter sets are qualitatively similar. We also notice from this figure that there are three minima in the energy surfaces of both the nucleus ^{292}120 and ^{288}118, at around β_2 = -0.15, +0.15, +0.55. Further getting a minima beyond $\beta_2 \sim 1.0$, which shows the fission path of these nuclei. Therefore, we can say that there is a superdeformed solution or a shape co-existence with $\beta_2 \sim 0.0$. This can be verified from the numerical results shown in Table I, that both the nucleus ^{292}120 and ^{288}118 have the superdeformed solutions in the ground state configuration. So, it can be the ground state of these nuclei. We, can conclude that the existence of the superdeformed solution for superheavy nuclei is independent of the models and their force parameters, in the RMF and SHF models.

The superdeformed solution as the lowest solution in the potential energy surface in case of ^{287}114 and ^{292}118 nuclei has been reported by Z. Ren and H. Toki [1, 2]. Their results are in agreement with our calculations which also predict that many superheavy nuclei are superdeformed in their ground state. Recently, I. Muntian and A. Sobiczewski [7] has claimed that they have considered superheavy nuclei within a macroscopic-microscopic approach, and their results do not support the prediction of superdeformed ground state for superheavy nuclei. They have studied the superheavy nucleus ^{292}118 and also other nuclei. But, their calculations do not forecast a superdeformed ground state for these nuclei. Further, it is investigated by A. Sobiczewski et al. [7] that superdeformed state prevails as long as the symmetric condition of the z-axis retain. However, this configuration washed away by inserting reflectional asymmetry. But, we do not get any significant change in the PES diagram confirming the existence of superdeformed states of these SHE.

Further, we will be presenting the energy surface results using constrained RMF calculations. These results will include the octupole degree of freedom which is important in and beyond the second minimum.

References

[1] Z. Ren, H. Toki, Nucl. Phys. **A689**, 691 (2001).

[2] Z. Ren, Phys. Rev. **C65**, 051304 (R) (2002).

[3] E. Chabanat, P. Bonche, P. Hansel, J. Meyer, and R. Schaeffer, Nucl. Phys. **A627**, 710 (1997).

[4] J. Boguta, A. R. Bodmer, Nucl. Phys. **A292**, 413 (1977).

[5] M. Bhuyan, S. K. Patra, and Raj K. Gupta, Phys. Rev. **C84**, 014318 (2011).

[6] S. K. Patra, F. H. Bhat, R. N. Panda, P. Arumugam, and R. K. Gupta, Phys. Rev. **C79**, 044303 (2009).

[7] I. Muntian and A. Sobiczewski, Phys. Letts. **B586**, 254 (2004).