Proporties of the superheavy Z=122 isotopes

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Introduction

The stability of nuclei in the superheavy mass region was predicted in mid sixties, when shell correction was added to the liquid drop binding energy and the possible shell closures were predicted at Z=114 and N=184. Recently, using the relativistic mean field (RMF) and the non-relativistic Skyrme Hartree-Fock (SHF) formalisms, within the microscopic theoritical calculations various other regions of stability are predicted as the shell closers beyond Z=82 and N=126 [1–3].

More recently, Marinov *et al.* [4] obtained a possible evidence for the existence of a long-lived superheavy nucleus with mass number A=292 and atomic number Z=122 or 124 in natural Thorium. The half life is estimated to be $T_{1/2} \geq 10^8$ y and abundance (1-10)$\times 10^{-12}$ relative to ^{232}Th. The possibility of such an extremely heavy Z nucleus motivated us to see the structural properties of such nuclei in an isotopic mass chain.

Theoretical Framework

We have used both the non-relativistic Skyrme Hartree-Fock (SHF) method [5] with SkI4 parameter set, and the axially deformed relativistic mean field (RMF) formalism [6] with NL3 parameter set. The BCS approach [7] is adopted to take care of the pairing effect (see also Ref. [8]).

Result and Discussion

Using the constrained method of calculation for both the SHF and RMF theories, we first obtained the potential energy surfaces (PES) for the ^{292}122 nucleus, as plotted in FIG. 1.

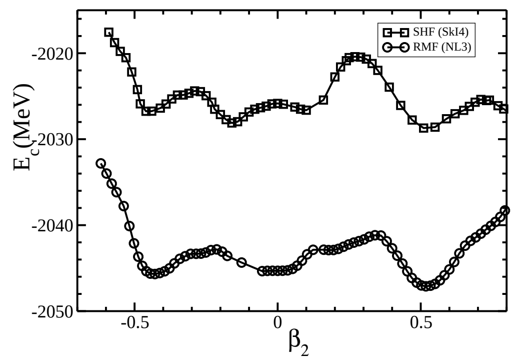

FIG. 1: The potential energy surfaces for ^{292}122 nucleus as a function of quadrupole deformation parameter β_2. The squares with solid-line is for SHF using SkI4 parameter set, and the circles with solid-line is for RMF calculations using NL3 parameter set.

The binding energy (BE), root-mean-square charge radius r_c and quadrupole deformation parameter β_2 for the ground state (g.s.) as well as for the excited state (e.s.) of the isotopic chain of Z=122 for both the methods are compared with the Finite Range Droplet Model (FRDM) result [9] in TABLE I for some isotopes.

For calculating the α-decay chain of the nucleus ^{292}122 (Z=122, N=170), our results for Q_α energy and the half-life time T_α are compared with the FRDM results[9] as well as the experimental data [10] in TABLE II.

Summary and Conclusion

In summary, we found qualitatively similar results for the g.s. as well as for the e.s. in both the RMF and SHF methods for the isotopic chain of Z=122. A shape change from oblate to prolate deformation is observed

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TABLE I: The SHF(SkI4) and the RMF(NL3) results for binding energy (BE), two-neutron separation energy S_{2n} and the quadrupole deformation parameter β_2, compared with the Finite Range Droplet Model (FRDM) data. The energy is in MeV.

	SHF(SkI4 parameter set)			RMF(NL3 parameter set)			FRDM results		
Nucleus	BE	S_{2n}	β_2	BE	S_{2n}	β_2	BE	S_{2n}	β_2
294	2045.52	16.29	0.534	2062.49	16.71	0.530	2053.16		-0.155
296	2061.74	15.94	0.529	2078.46	16.21	0.527	2068.99	15.84	-0.130
298	2077.44	15.34	0.526	2093.81	15.70	0.536	2084.26	15.26	-0.096
300	2092.62	14.81	0.526	2108.67	15.18	0.548	2099.64	15.38	0.009
304	2121.47	13.82	0.545	2136.83	14.17	0.603	2126.87	12.89	0.000

TABLE II: The Q_α and T_α calculated on the SHF(SkI4) and the RMF(NL3) models, and compared with the Finite Range Droplet Model (FRDM) results as well as the experimental data [10], wherever available. The binding energies marked with star (*) are the extrapolated values. The energy is in MeV and the half-life time in second.

		SHF(SkI4 parameter)			RMF(NL3 parameter)			FRDM results			Expts. [10]		
Nucleus	Z	BE	Q_α	T_α	BE	Q_α	T_α	BE	Q_α	T_α	BE	Q_α	T_α
292	122	2028.8	14.3	$10^{-7.23}$	2046.2	13.8	$10^{-6.35}$						
288	120	2014.8	13.1	$10^{-5.49}$	2031.7	12.3	$10^{-3.85}$	2023.0	13.9	$10^{-6.07}$			
284	118	1999.6	14.8	$10^{-9.11}$	2015.8	12.8	$10^{-5.48}$	2008.7	12.7	$10^{-4.08}$			
280	116	1986.2	13.9	$10^{-7.93}$	2000.3	12.9	$10^{-6.10}$	1993.5	12.4	$10^{-5.10}$			
276	114	1971.8	12.3	$10^{-5.37}$	1984.9	11.8	$10^{-4.33}$	1977.6	12.3	$10^{-5.44}$			
272	112	1955.8	12.3	$10^{-5.97}$	1968.5	11.4	$10^{-4.07}$	1961.6	11.6	$10^{-4.45}$			
268	110	1939.8	11.8	$10^{-5.54}$	1951.6	10.9	$10^{-3.41}$	1944.9	10.9	$10^{-3.47}$	1943.0*	11.5	$10^{-4.76}$
264	108	1923.4	10.2	$10^{-2.34}$	1934.2	10.2	$10^{-2.19}$	1927.6	10.5	$10^{-3.18}$	1926.6	10.6	$10^{-3.3}$
260	106	1905.3	9.6	$10^{-1.10}$	1916.1	9.9	$10^{-2.27}$	1909.9	9.9	$10^{-2.15}$	1908.9	9.7	$10^{-1.5}$

with increase of isotopic mass number at A=290. The ground-state structures are highly deformed which are in agreement with the observations of Ref. [4] for the superheavy region. From the binding energy analysis, we found that the most stable isotope in the series is ^{302}122, instead of the observed ^{292}122, considered to be a neutron-deficient nucleus. Our predicted α-decay energy Q_α and half-life time T_α agree nicely with the FRDM calculations, and available experimental data.

References

[1] K. Rutz *et al.*, Phys. Rev. C **56**, 238 (1997).

[2] S. K. Patra, C. -L. Wu, C. R. Praharaj, and R. K. Gupta, Nucl. Phys. A **651**, 117 (1999).

[3] R. K. Gupta, S. K. Patra, and W. Greiner, Mod. Phys. Lett. A **12**, 1727 (1997).

[4] A. Marinov, I. Rodushkin, D. Kolb, A. Pape, Y. Kashiv, R. Brandt, R. V. Gentry, and H. W. Miller, arXiv: 0804.3869v1 (nucl-ex), and to be published in Int. J. Mod. Phys. E (2009).

[5] J. R. Stone and P. -G. Reinhard, Prog. Part. Nucl. Phys. **58**, 587 (2007).

[6] B. D. Serot and J. D. Walecka, Adv. Nucl. Phys. **16**, 1 (1986).

[7] D. G. Madland and J. R. Nix, Nucl. Phys. A **476**, 1 (1981);

[8] S. K. Patra, M. Bhuyan, M. S. Mehta and R. K. Gupta, Phys. Rev. C **80**, 034312 (2009).

[9] P. Möller *et al.*, At. Data and Nucl. Data Tables **59**, 185 (1995); P. Möller *et al.*, At. Data and Nucl. Data Tables **66**, 131 (1997).

[10] G. Audi, A. H. Wapstra, and C. Thibault, Nucl. Phys. A **729**, 337 (2003).