Study of Bubble Structure in the Superheavy Nuclei

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Introduction

In past few years, the synthesis of transuranic superheavy elements in various laboratories is an important study in Nuclear Physics. It is to be noted that these elements are only synthesized and till date, the properties are mostly unknown due to their shorter lifetime. It is also the current interest to know the next magic number beyond ^{208}Pb. That means, what is the next double close nucleus in the superheavy region.

In the present work, our aim is to study the properties of the recently synthesized superheavy nuclei from $Z = 105$ to 118, along with theoretically predicted next magic nuclei $Z = 120$. We have studied the ground state and intrinsic exited state i.e. prolate, spherical and oblate by using the relativistic mean field theory(RMF-NL3*). We also calculate the charge radius, quadrupole deformation parameter and lifetime of the α-decay chain.

Theory

The RMF theory is applied successfully to study the structural properties of nuclei throughout the periodic table starting from proton to neutron drip-lines. The starting point of the RMF theory is the basic Lagrangian containing nucleons interacting with $\sigma-$, $\omega-$ and $\rho-$meson fields. The photon field A_μ is included to take care of the Coulomb interaction of protons. The relativistic mean field Lagrangian density is well known and can be found in reff. [1].

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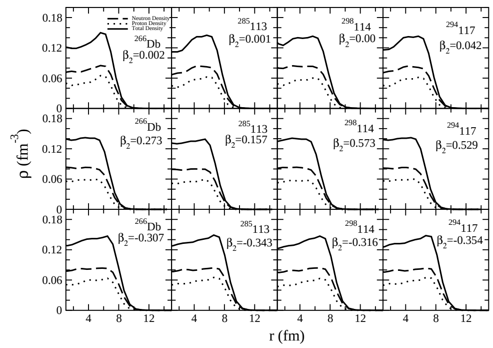

FIG. 1: We are taking the some selected nuclei and plot their nucleons density .

Result and Discussion

A. Bubble Structure

The density of a nucleus has the gross information about the size, shape and distribution of nucleons. We plotted the density distribution of the nuclei, there is the deep at the central region. Which shows the bubbleness of the nuclei. For quantitative understanding, we can calculate the depletion factor(D.F.) by using this formula

$$D.F. = \frac{\rho_{max.} - \rho_{cent}}{\rho_{cent}}. \quad (1)$$

For some of the specific cases, the D.F. value are listed in table I. From the table I it is clear that some of the nuclei posses bubble structure in the intrinsic excited state.

B. Shape Co-existance

When a nucleus have same binding energy for the different shapes (spherical, prolate, oblate) then this situation is called 'Shape Coexistance'. Due to this, nucleus can be oscillate from one state to another state by perturbing small energy. There are many nuclei,

TABLE I: In this table we are taking only Db isotopes nuclei for depletion factor and **s** stand for spherical,**p** for prolate and **o** for oblate shape respectively.

Nucl	DF_{sn}	DF_{sp}	DF_{pn}	DF_{pp}	DF_{on}	DF_{op}
^{266}Db	19.57	18.00	1.22	2.95	5.22	20.05
^{267}Db	19.79	18.11	1.04	1.91	5.28	15.67
^{268}Db	19.98	18.29	0.92	2.92	4.08	20.32
^{269}Db	20.20	18.52	0.87	1.55	4.19	20.66
^{270}Db	20.40	18.78	0.87	1.23	4.27	21.14

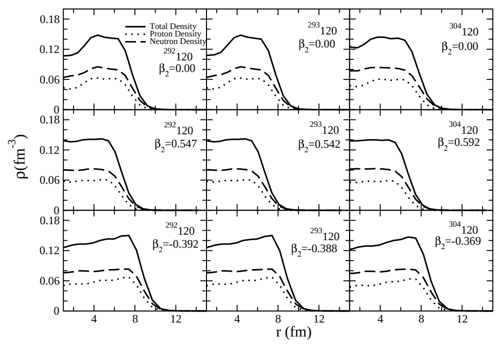

FIG. 2: Density plot for $Z = 120$ nucleus.

which show such type of properties but here we presented only few cases.

TABLE II: In this table we are taking Z=120 isotopes for the shape co-existance of the nuclei **s** stand for spherical,**p** for prolate and **o** for oblate shape respectively.

Nucl	BE(s)	BE(p)	BE(o)	β_2(s)	β_2(p)	β_2(o)
^{292}120	2061.5	2060.8	2057.9	0.000	0.547	-0.392
^{293}120	2068.7	2068.3	2065.1	0.000	0.542	-0.388
^{304}120	2139.3	2142.4	2137.4	0.000	0.592	-0.369

C. Stability and Lifetime

Stability of the nucleus is directly connected with the binding energy per nucleon or Q_α which can be calculated by eqn (2) and lifetime by Seaborg and Viola formula (3).

$$Q_\alpha = BE(N,Z) - BE(N-2,Z-2) - BE(2,2) \quad (2)$$

$$\log_{10}(T_\alpha) = \frac{(aZ+b)}{\sqrt{Q_\alpha}} + (cZ+d) + h\log \quad (3)$$

All the terms having their usual meaning and the value of these constants are in Ref. [2]. The obtained result are compared with the FRDM calculation and extrapolated datawherever possible. The results are given in table II and III.

TABLE III: In this table we are taking Db ,Sg and Bh nuclei isotopes. In table f stand for FRDM data.

Nucl	Q_α	${Q_\alpha}^f$	${Q_\alpha}^{exp}$	T_α	${T_\alpha}^f$
^{266}Db	7.17	7.36		8.87×10^7s	$10^{7.15}$s
^{267}Db	7.15	7.09		4.84×10^7s	$10^{7.96}$s
^{268}Db	7.49	7.19		4.23×10^6s	$10^{7.87}$s
^{269}Db	7.98	7.59		2.32×10^4s	$10^{6.95}$s
^{270}Db	8.19	7.84	8.80±0.1	9073.49s	$10^{5.25}$s
^{258}Sg	9.48	9.45		0.13s	$10^{-0.83}$s
^{260}Sg	9.33	9.93		0.34s	$10^{-2.15}$s
^{262}Sg	9.04	9.61		2.63s	$10^{-1.26}$s
^{271}Sg	8.88	8.40	8.54±0.08	95.39s	$10^{3.55}$s
^{270}Bh	8.92	8.18	8.93±0.08	173.58s	$10^{4.76}$s
^{272}Bh	9.61	8.88	9.01	1.49s	$10^{2.36}$s
^{274}Bh	8.34	8.71	8.80±0.1	14779.07s	$10^{2.93}$s

Conclusion

Our result of binding energy BE, α-decay energy Q_α and lifetime T_α have well matched with the extrapolated experimental result [3] and with the theoretical prediction of Moller et al. [4].

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