Alpha Decay Half-life and Ground State Properties of Super heavy Nuclei in RMF Description

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Introduction

The experimental study of Superheavy Nuclei (SHN) is quite challenging due to their small cross-section and the short decay half-life. Moreover the subject requires to be intensely supplemented by theoretical information of SHN, in terms of nuclear structure features such as deformation, shell effect, and stability, which can be helpful in identifying these α-emitters as well as their properties. As the prominent mode of decay is alpha decayin SHN, one can predict the nuclear structure details by analyzing decay chain and the decay half-life. Such an information gained can be duely confirmed with number of models available. There have been many phenomenological microscopic models developed in the past to predict alpha decay half-life on the basis of Gamow's quantum tunneling theory of alpha decay.

Mathematical Formalism

In order to predict the decay half-life, Q_α value and other ground state properties such as neutron skin, shell closure we have used Relativistic Mean Field theory. This is done by solving density dependent RHB equation self-consistently. Using the RHB framework, we have calculated matter radii, matter density, the mass of nuclei, charge radii, binding energy, and quadrupole deformation. This has been done using two parameter sets DDME2 and DDPC1. The calculated mass in DDME2 [3] parameter set has been further used to calculate the Q_α value of reaction and mass excess data to predict decay half-life. The decay half-life of SHN has been calculated by using shape parametrization model [6] by fitting inertial and mass parameters.

Result and Discussion

As the reliability of any theoretical model depends on the fact that how accurately the model predicted experimental data, therefore we have calculated ground state binding energy of experimentally observed even-even SHN in spherical as well as axially deformed harmonic oscillator basis and compared the same with the experimental results as available, as given in the table 1.

Table 1: The calculated results (DDME2, DDPC1) for binding energy in experimentally observed even-even super heavy nuclei with Experimental[5] and FRDM[2] result –

Nuclei	**Binding energy per nucleon (MeV)**			
$_ZX^A$	**Exp.**	**DDME2**	**DDPC1**	**FRDM**
$_{106}Sg^{258}$	7.342	7.334	7.325	7.346
$_{106}Sg^{260}$	7.342	7.334	7.325	7.346
$_{106}Sg^{262}$	7.341	7.332	7.324	7.344
$_{106}Sg^{264}$	7.338	7.328	7.320	7.341
$_{106}Sg^{266}$	7.332	7.332	7.315	7.338
$_{108}Hs^{264}$	7.298	7.289	7.279	7.302
$_{108}Hs^{266}$	7.298	7.288	7.279	7.303
$_{108}Hs^{270}$	7.295	7.240	7.233	7.302
$_{110}Ds^{270}$	7.254	7.244	7.234	7.262
$_{112}Cn^{282}$	7.197	7.184	7.175	7.209
$_{112}Cn^{284}$	7.190	7.172	7.161	7.204
$_{114}Fl^{284}$	7.162	7.142	7.130	7.176
$_{114}Fl^{286}$	7.159	7.144	7.130	7.174
$_{114}Fl^{288}$	7.154	7.137	7.125	7.171
$_{116}Lv^{290}$	7.120	7.106	7.091	7.134
$_{116}Lv^{292}$	7.116	7.101	7.087	7.132
$_{118}Og^{294}$	7.120	7.086	7.050	7.092

In the table we have shown the calculated binding energy for even-even isotopes, and one can see that the calculated BE/A are almost similar to the experimental value. In a comparative study of DDME2 and DDPC1 result, the DDME2 result shows the least root mean square deviation with respect to experimental value. To extrapolate the region of experimentally unobserved even-even isotopes of super heavy nuclei we have calculated Q_α value of the reaction which is enriched with the structural properties of nuclei. The calculated Q_α value of nuclear reaction for experimentally observed and for those nuclei which will synthesize in the near future is also shown in the plot.

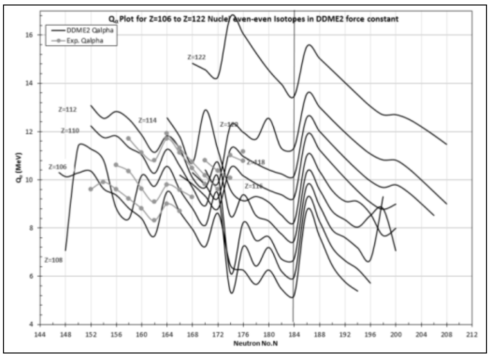

Fig. 1: The calculated Q_α plot as a function of neutron no. for even-even isotopes of Z=106 to Z=122 nuclei in the framework of DDME2 parameter set, the solid line shows the calculated result and, solid circles show experimental data

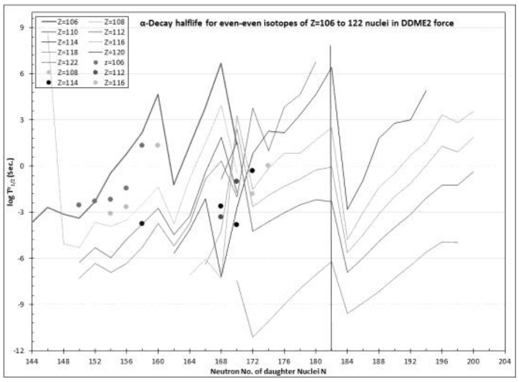

Fig. 2: The calculated decay half-life on a logarithmic scale as a function of neutron no. of daughter nuclei for even-even isotopes of Z=106-122 nuclei

The calculated Q_α value for Z=106-122 nuclei with experimental results has been shown in the figure and the shell gap at N=184,198 can be clearly seen in figure 1 where Q_α shows minima. In figure 2 we have shown the calculated decay half-life using shape parameterization model in DDME2 predicted mass excess data and the results are very consistent with the experimental decay half-life for observed nuclei. The maxima in decay half-life at N=184,198 clearly indicate the shell closure stability against fission. We have also calculated the neutron skin, and matter radii to observe the variation as a function of asymmetry which shows a linear relation with neutron skin. The detailed study for SHN studies in this work will be presented in the conference.

Conclusion

In summary, we have studied the ground state observables such as BE, Neutron skin, rms radii, charge radii, shell gap, Q_α value, and α-decay half-life in RHB using DDME2 parameterization for Z=106-122 nuclei for even-even isotopes. As some of the nuclei are planned to be synthesized in the near future, therefore such studies of SHN have considerable importance.

Acknowledgement

Akhilesh Kumar Yadav is highly thankful to CSIR-UGC for providing financial support under the UGC-JRF fellowship scheme to carry out this work.

References

[1] M. Gonsalves, S.B. Duarte, Phys. Rev. C **48**, 2409 (1993).

[2] P. Möller, J. R. Nix, K. L. Kratz, Atom. Data Nucl. Data Tables 66, 131 (1997).

[3] T. Niksic, D. Vretenar, P. Finelli, P. Ring
Phys. Rev. C **66**, 024306 (2002).

[4] A. Shukla, S. Åberg, Awanish Vajpeyi, J. Phys. G: Nucl. Part. Phys. **44**, 025104 (2017) and references therein.

[5] https://www.nndc.bnl.gov.in

[6] M. Gonḉalves, S. B. Duarte, F. Garcia, O. Rodriguez, Comp. Phys. Com. **107**, 246 (1997).