Possible shell or sub-shell closure around A= 220

R. R. Swain[1], C. Dash[2], P. K. Moharana[3], I. Naik[2], and B. B. Sahu[1*]
[1] *Department of Physics, School of Applied Sciences, KIIT, Deemed to be University, Odisha-751024, INDIA*
[2] *Department of Physics, North Orissa University, Baripada-757003, INDIA and*
[3] *Department of Physics, KISS, Deemed to be University, Odisha-751024, INDIA*

Heavy nuclei with Z$\geq$ 82 are generally less accessible for detailed studies with usual nuclear spectroscopy methods. Therefore the study of half lives via α-decay and/or cluster decay represents one of the main tools for the nuclear structures as well as spectroscopy of ground and excited states of a nuclei in the mass region A=220 [1, 2]. Again, the mass region of A$\sim$220 is crucial because there is strong specific evidence that in certain heavy and/or super-heavy regions, octupole-deformed atomic nuclei are distorted into a pear shape [3]. The major purpose of the present study is to examine the α and cluster decay processes in the region of A$\sim$220 of Ra isotopes to predict the existence of spherical shell/sub-shell closures in the daughter lead region within an axially deformed relativistic mean field (RMF) theory with NL3 force parameter set. The Q-value is obtained from the binding energies of the nuclei. With this Q-value we examine the α-decay as well as cluster decay half-life of Ra isotopes using the Viola-Seaborg [4], Royer [5, 6], universal decay law (UDL) [7, 8] and universal formula (UNIV) of Poenaru et al. [9]. Along with the structural study of Ra isotopes, we also show how the half-lives are sensitive to the shell closures of parent and daughter nuclei. It is clear that cluster radioactivity is related to shell/sub-shell closure, so it is very important to evaluate how much the shell effects impart to the half-life for α and cluster radioactivity. This is the primary motivation for this work.

The key point in the cluster radioactivity is that it involves the interplay of close shell effects of parent and daughter. Small half life for a parent indicates shell stabilized daughter and long half life

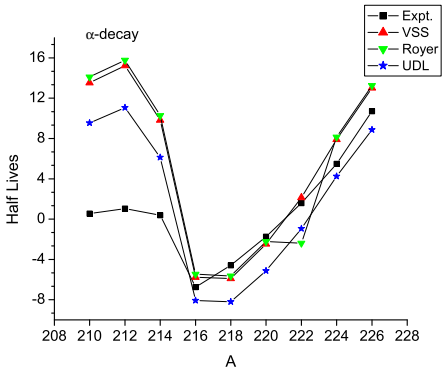

FIG. 1: Plot of alpha decay half life as a function of mass number of Ra isotopes.

indicates the stability of the parent against the decay. In the cluster decay of trans lead nuclei observed, the end product is doubly magic lead or its neighbors. With this in our mind we have extended the idea of cluster radioactivity. It is found from Fig.1 that the half-life is small for the parent nucleus ^{216,218}Ra as per the VSS, Royer and UDL formalism. Hence the possible shell is stabilized at the daughter nucleus ^{212,214}Rn when an α particle is emitted. From Fig.2 it is observed that when ^{8}Be is emitted from Ra isotopes, the half-life is small for the ^{218}Ra nucleus which indicates possible shell and/or sub-shell closure at ^{210}Po. When isotopes of C are emitted from Ra isotopes, it is found from the Fig.3 that there is remarkable agreement between the experimental and calculated half-lives of ^{222}Ra and ^{224}Ra. Where ^{224}Ra shows a small half-life, implying that the daughter nucleus ^{208}Pb is the obvious stable one. The decrease in half-lives is due to the double magicity

*Electronic address: bbsnou@gmail.com

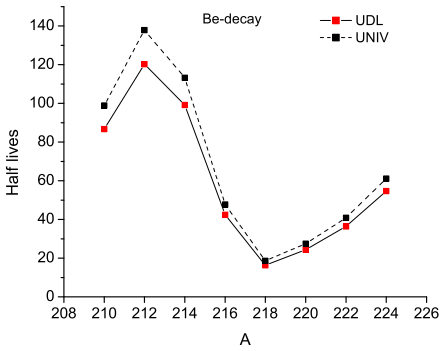

FIG. 2: Plot of Be-decay half life as a function of mass number of Ra isotopes.

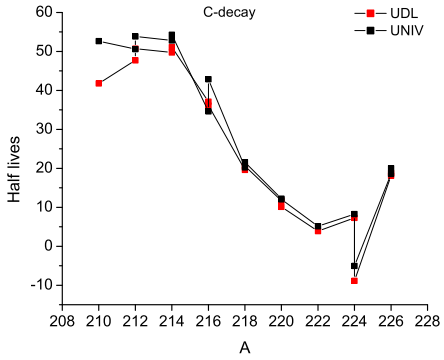

FIG. 3: Plot of C-decay half life as a function of mass number of Ra isotopes.

(Z=82, N=126) of the well known ^{208}Pb daughter and the sensitivity of half-life to angular momentum L and Q-value. In Fig.4 we show the cluster decay half-life of O isotopes using the UDL and the universal formula. Both calculations show a small half-life for ^{224}Ra and hence the shell stabilization at ^{206}Hg is expected with the emission of ^{18}O.
So our calculated Q-value obtained with RMF formalism is suitable for explaining cluster radioactivity from heavy and superheavy nuclei, along with the study of ground state properties. In conclusion, the calculated half-lives of alpha and other characteristics pertaining to possible cluster emissions with the Q-values obtained from RMF model have been computed and shown in above figures found that the cluster emissions, provide a great contribution to the study of half-lives for Ra isotopes.

This work is supported by SERB, DST, Govt. of India, vi-de Grant No-SR/FTP/PS-106/2013.

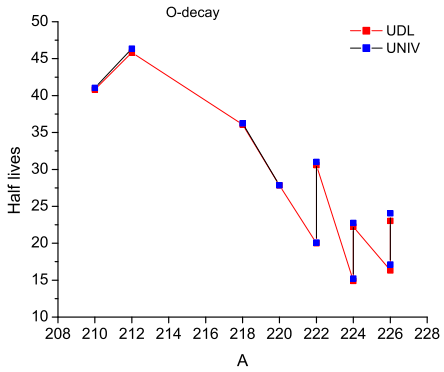

FIG. 4: Plot of O-decay half life as a function of mass number of Ra isotopes.

References

[1] Rashmirekha Swain et al., Chinese Phys. C **42** 084102 (2018).
[2] D. Bucurescu and N. V. Zamfir, Phys. Rev. C **87**, 054324 (2013).
[3] L. P. Gaffney, et. all., NATURE, **497**, 199 (2013).
[4] V. E. Viola, Jr. and G. T. Seaborg, J. Inorg. Nucl. Chem. **28**, 741 (1966).
[5] G. Royer, Nucl. Phys. A **848**, 279 (2010).
[6] J. M. Dong, et al., Nucl. Phys. A. **832**, 198 (2010).
[7] C. Qi, F. R. Xu, R. J. Liotta and R. Wyss, Phys. Rev. Lett. **103**, 072501 (2009).
[8] C. Qi, F. R. Xu, R. J. Liotta, R. Wyss, M. Y. Zhang, C. Asawatangtrakuldee and D. Hu, Phys. Rev. C **80**, 044326 (2009).
[9] D. N. Poenaru, R. A. Gherghescu, W. Greiner, Phys. Rev. C **83**, 014601 (2011).