Half-life values in heavy elements using Relativistic mean field model

S. Mahapatro[1]*
[1] *Department of Physics, Ravenshaw University, Cuttack-753003, India.*

Introduction

The α decay is one of the most important decay modes for unstable nuclei. Measurements on α decay of ground state nuclei can provide reliable information on nuclear structure such as ground state energy, ground state life-time and nuclear spin and parity. Measurements on α decay are also used to identify new nuclides or new elements because α decay is a clean and reliable mode to extract information on the parent nuclei[1]. To-date there are more than 400 nuclei in the periodic table that exhibit α decay phenomena.

In recent years, there has been renewed interest in α decay because of development of radioactive beams and new detector technology under low temperature[2, 3]. We studied favoured α decay half-lives for two different mass regions.

I. THEORY

The successful applications of Relativistic Mean Field Model(RMF) formalism both in finite and infinite nuclear systems make more popular of the formalism in the present decades. The use of RMF are well documented and details can be found in [4, 5]. The $\alpha-$ decay energy Q_α is obtained from the relation [6]: $Q_\alpha(N,Z) = BE(N,Z) - BE(N-2, Z-2) - BE(2,2)$. Here, $BE(N,Z)$ and $BE(N-2,Z-2)$ are the binding energy of the parent and daughter nucleus, respectively. The $BE(2,2)$ is the binding energy of the α-particle (^{4}He), i.e. 28.296 MeV. The binding energies of the parent and daughter nuclei are obtained from RMF formalism. From these BE values, we evaluate the Q_α energy by using the above algebraic formula [6].

With the Q_α energy, we estimate the half-life $T^\alpha_{1/2}$ by using two different phenomenological formula such as Viola and Seaborg [7]. The expression for the Viola and Seaborg [7] is given by:

$$log_{10}T^\alpha_{1/2}(s) = \frac{aZ-b}{\sqrt{Q_\alpha}} - (cZ+d) + h_{log}, \quad (1)$$

with Z as the number of proton for the parent nucleus and the constants a, b, c and d, are from Sobiczewski et al. [8]. The value of these constants are $a = 1.66175$, $b = 8.5166$, $c = 0.20228$, $d = 33.9069$ and the quantity h_{log} accounts for the hindrances associated with the odd nucleon as,

$$\begin{aligned} h_{log} &= 0 for \text{ Z even and N even} \\ &= 0.772 for \text{ Z odd and N even} \\ &= 1.066 for \text{ Z even and N odd} \\ &= 1.114 for \text{ Z odd and N odd.} \end{aligned} \quad (2)$$

The relativistic mean field (RMF) [9] Lagrangian with NL3 parameter set [10] contained interaction between meson and nucleon and also self interacting sigma meson. The other mesons are the omega and rho fields. The photon field A_μ is included to take care of Coulombic interaction of protons. A set of coupled equations are obtained from the Lagrangian, which are solved numerically in an axially deformed harmonic oscillator basis taking 12 bosonic and Fermionic oscillator quanta [11]. In this model pairing and center of mass correction are added externally [9].

Result and Discussion

The results of our calculation are presented in Table-1. Then we estimated Q_α and $T^\alpha_{1/2}$

*Electronic address: narayan@iopb.res.in

TABLE I: The binding energy BE, charge radius r_{ch}, quadrupole deformation parameter β_2, Q_α, $T^\alpha_{1/2}$ of heavy nuclei by using RMF(NL3) formalism. The energy is in MeV and radius results are in fm.

Nucleus	BE	r_{ch}	β_2	Q_α	$T^\alpha_{1/2}$
^{238}Cm	1800.5	5.91	0.28	5.90	7.16x 10^8s
^{240}Cm	1813.8	5.93	0.28	5.72	6.62x 10^9s
^{242}Cm	1826.6	5.94	0.29	5.12	2.43x $10^1$3s
^{240}Cf	1807.3	5.93	0.27	7.47	5.61x 10^2s
^{242}Cf	1821.4	5.95	0.28	7.37	1.27x10^3s
^{244}Cf	1835.2	5.36	0.29	6.91	9.87x10^4s
^{248}Cf	1860.2	5.99	0.29	6.95	6.30x10^4s
^{250}Cf	1871.3	6.00	0.29	6.78	3.62x10^5s
^{250}Fm	1868.2	6.02	0.30	7.63	8.96x10^2s
^{252}Fm	1881.2	6.03	0.29	7.33	1.24x10^4s
^{250}No	1862.4	6.03	0.29	7.85	8.19x10^2s
^{252}No	1876.4	6.04	0.29	8.12	89.9s
^{254}Rf	1882.0	6.06	0.30	8.77	3.35s
^{252}Sg	1852.4	6.07	0.29	9.80	1.58x10^{-4}s
^{256}Hs	1870.3	6.11	0.30	10.36	2.26x10^{-3}s
^{252}Ds	1813.7	6.14	0.37	11.89	2.44x10^{-6}s
^{254}Ds	1832.6	6.14	0.34	11.67	7.28x10^{-6}s

for all these isotopes using the BE values. Our predicted results are are compared with [12, 13]. We observe that the Q_α obtained from RMF (NL3) formalism are comparable with the results of other calculations. A further inspection of the results suggest that the present results have some scope to improve.

Conclusion

In summary, we have calculated the bulk properties like binding energy, charge radius, quadrupole deformation parameter of heavy mass region using RMF(NL3) formalism and also investigated the Q_α, $T^\alpha_{1/2}$ for these heavy region having Z= 96-110. We found that our results are comparable with other calculations as well as available data. The decay and other related properties will be discussed at the time of presentation.

References

[1] G. Audi, O. Bersillon, J. Blachot and A. H. Wapstra, *Nucl. Phys. A* **729**, (2003) 3.

[2] S. Hofmann and G. Munzenberg, *Rev. Mod. Phys* **72** (2000)733.

[3] Yu. Ts. Oganessian et al., *Phys. Rev. C* **74** (2006) 044602.

[4] R. J. Furnstahl, B. D. Serot and H. B. Tang, *Nucl. Phys. A* **615** (1997)441.

[5] S. K. Patra and C. R. Praharaj, *Phys. Rev. C* **44** (1991) 2552.

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

[7] V. E. Viola, Jr. and G. T. Seaborg, J. Inorg. Nucl. Chem. **28**, 741 (1966).

[8] A. Sobiczewski, Z. Patyk, and S. C. Cwiok, Phys. Lett B **224** 1 (1989).

[9] J. Boguta and A. R. Bodmer, *Nucl.Phys. A* **292** (1977) 413.

[10] S. K. Patra and C. R. Praharaj, *Phys. Rev. C* **47** (1993) 2978.

[11] W. Pannet, P. Ring and J. Boguta, *Phys.Rev. Lett.* **59** (1987) 21.

[12] P. Möller, J. R. Nix and K. -L. Kratz, *Atomic and Nucl. Data Tables* **66** (1997) 131.

[13] I. Silisteanu, A. I. Budaca and A. O. Silisteanu, *Rom. J. Phys.* **55** (2010) 1088.