Q_α and $T^{\alpha}_{1/2}$ values in Superheavy elements using Relativistic mean field model

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Introduction

The study of unstable heavy nuclei near drip-line region of the nuclear chart has opened a new area of research in the nuclear structure physics of finite systems [1–4]. The study is not only an interest in nuclear theory but also enrich the information regarding the synthesis of new element due to stellar evolution [5–7]. Further the elements in this region, such as Z= 120-128 are very rare ones known on the earth and they are only observed in nature by the decay chains of heavy elements.

In recent years, there has been renewed interest in α decay because of development of radioactive beams and new detector technology under low temperature[8, 9]. 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 [10, 11]. The $\alpha-$ decay energy Q_α is obtained from the relation [12]: $Q_\alpha(N,Z) = BE(N,Z) - BE(N-2, Z-2) - BE(2,2)$. 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 [12].

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 [13]. The expression for the Viola and Seaborg [13] 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. [14]. 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,

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

The relativistic mean field (RMF) [15] Lagrangian with NL3 parameter set [16] 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 [17]. In this model pairing and center of mass correction are added externally [15].

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TABLE I: The RMF(NL3) results for binding energy BE,charge radius r_{ch}, quadrupole deformation parameter β_2, of spherical and superheavy nuclei. The energy is in MeV and radius results are in fm.

A	Z	BE	r_{ch}	β_2	Q_α	t_α
276	122	1899.086	6.30	0.272	15.33	1.06x10^{-9}
278	122	1919.558	6.31	0.267	15.39	8.48x10^{-10}
280	122	1939.343	6.32	0.264	15.30	1.16x10^{-9}
282	122	1958.331	6.33	0.261	15.16	2.02x10^{-9}
284	122	1976.804	6.34	0.256	14.81	7.51x10^{-9}
286	122	1994.108	6.34	0.245	15.25	1.39x10^{-9}
288	122	2010.834	6.34	0.215	15.88	1.40x10^{-10}
290	122	2027.087	6.34	0.197	16.35	2.81x10^{-11}
292	122	2042.509	6.35	0.188	16.55	1.43x10^{-11}
294	122	2062.563	6.59	0.534	12.65	1.04x10^{-4}
296	122	2078.560	6.59	0.530	13.06	1.44x10^{-5}
286	124	1970.766	6.36	0.258	15.86	4.09x10^{-10}
288	126	1962.009	6.49	0.418	17.92	1.14x10^{-12}

Result and Discussion

The results of our calculation are presented in Table-1. Then we estimated Q_α and $T^\alpha_{1/2}$ for all these isotopes using the BE values. 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= 120-128. 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.

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