Alpha Decay Chains of $^{293-295}$Og Isotopes

Anupriya Das, Ashiq K M, and Nithu Ashok*
Department of Physics, S.A.R.B.T.M Government College Koyilandy, Kerala- 673307, INDIA

Introduction

Trans-actinides with $Z \geq 103$ are called super-heavy nuclei (SHN). SHN was synthesized in the laboratory by cold or hot fusion reactions. Oganassian is the heaviest element discovered so far and three isotopes of Og with mass number, A=293-295 are known to date. Exploration of the upper limit of the nuclear chart is a great challenge faced by nuclear physicists nowadays. We usually expect SHN to be short-lived, but the existence of nuclei in the vicinity of Z=114 and N=184 leads to the concept of an island of stability. Compared to other nuclei, the lifetime of SHN is very small. The dominant decay mode of SHN is alpha decay. SHN decay by alpha emission which leads to the formation of a new isotope. Experimental results show that, in the case of SHN, alpha decay, and spontaneous fission compete with each other.

In the present work, we have studied the alpha decay chains of the isotopes of the superheavy element, Oganesson (Og) with Z = 118 using the Effective Liquid Drop model (ELDM).

Theory

In ELDM, α and cluster decay are explained in a unified framework[1]. In this model, the potential energy contribution includes the Coulomb [2], surface, and centrifugal components.

The half-life for the decay is obtained as

$$T_{1/2} = \frac{ln2}{\lambda} \tag{1}$$

λ is the decay constant. It is calculated using

$$\lambda = \lambda_0 P \tag{2}$$

where λ_0 is the assault frequency ($\lambda_0 \approx 10^{22}s$). The barrier penetrability factor P is calculated using WKB approximation

$$P = exp\{-\frac{2}{\hbar}\int_{\zeta_1}^{\zeta_2}\sqrt{2\mu(V-Q)}d\zeta\} \tag{3}$$

Where μ is the inertia coefficient, which is obtained using effective inertia approximation.

The half-lives of α decay are also calculated using the following semi-empirical equations- (1) Universal Decay Law[3],(2) an empirical formula proposed by Horoi[4], (3) equation proposed by Royer[5] and (4)the Viola-Seaborg semi-empirical relationship(VSS)[6].

The half-life of spontaneous fission is determined using the semi-empirical formula of Xu[7].

$$T_{1/2} = exp\{2\pi[C_0 + C_1 A + C_2 Z^2 + C_3 Z^4 + C_4(N-Z)^2 - (0.13323Z^2/A^{1/3} - 11.6)]\} \tag{4}$$

The constants are $C_0 = -195.09227, C_1 = 3.10156, C_2 = -0.04386, C_3 = 1.4030 * 10^{-6}$ and $C_4 = -0.003199$

Result and discussion

The alpha decay half-lives of isotopes of SHN $_{118}Og$ in the mass range 293$\leq A \leq$295 have been calculated using ELDM. Since decay could occur only if the Q-value is positive, it is necessary to calculate the Q-value. The expression for the Q-value is,

$$Q = \Delta M_p - (\Delta M_\alpha + \Delta M_d) \tag{5}$$

The last term in this equation owing to the shield effect of atomic electrons on the proton. ΔM_p, ΔM_d, and ΔM_α are the mass excess of the parent, the daughter, and the emitted alpha particle respectively.The whole work is done by employing mass excesses taken from the theoretical mass table WS4+RBF[8].

*Electronic address: nithu.ashok@gmail.com

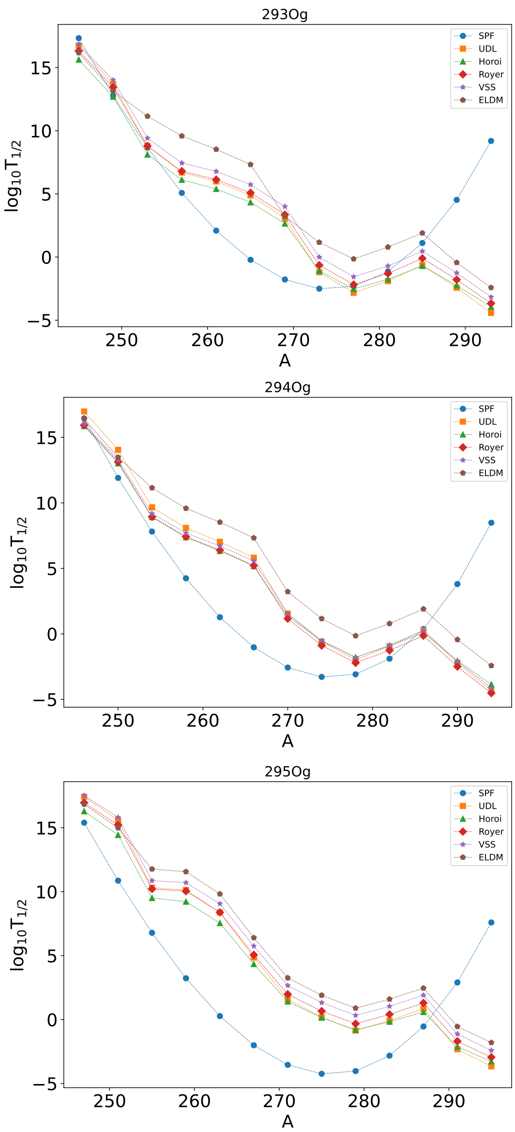

FIG. 1: Comparison of α decay half life with spontaneous fission half life of $^{293-295}$Og isotopes.

The half-lives of alpha decay predicted using ELDM are compared with those obtained using theoretical formulae UDL, HOROI, Royer's formula, and VSS. It is observed that all the selected models predict alpha decay chains in a similar fashion. The end of the alpha decay chains is characterized by spontaneous fission. The isotopes whose alpha decay half-lives are less than the spontaneous fission half-lives survive fission. The spontaneous fission half-lives are calculated using the semi-empirical formula of Xu. We have shown in figure 2, the isotopes in the alpha decay chains of the ^{293}Og isotopes. Similar decay chains can be observed for other isotopes. ELDM predicts 2-α-chains whereas, other semi-empirical formulae predicts 3α-chains from $^{293-295}$Og isotopes. Our predictions may help the experimentalists in their further research on the quest for new SHN.

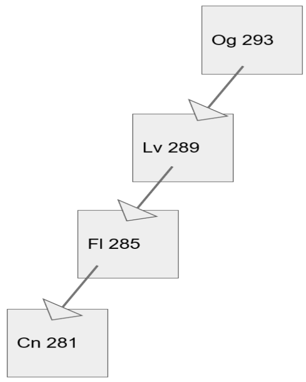

FIG. 2: Schematic representation of ^{293}Og decay chain.

References

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

[2] M. Gaudin, *J. Phys. (France)*, **35**, 885(1974).

[3] Dongdong Ni, Zhongzhou Ren, Tiekuang Dong and Chang Xu, *Phys.Rev. C*, **78**, 044310(2008).

[4] M. Horoi, J. Phys. G: Nucl. Part. Phys. 30 (7) (2004) 945–955.

[5] G. Royer, J. Phys. G: Nucl. Part. Phys. 26, 1149 (2000).

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

[7] C. Xu, Z. Ren, and Y. Guo, Phys. Rev. C 78, 044329 (2008).

[8] N. Wang, M. Liu, X. Wu, J. Meng, Phys. Lett. B, 734 215(2014).