Alpha decay Half-Life time of Rutherfordium and Seaborgium isotopes: Spontaneous Fission versus Alpha Decay

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***Abstract* - Currently the progress in Super Heavy Nuclei (SHN) is focused on their structure and properties, which concerns with both its theoretical and experimental findings. Generally elements with atomic number greater than ninety two are unstable and they decay to lighter nuclei with a characteristic life time values. The dominant decay modes of SHN for heavy and super heavy nuclei are alpha decay and spontaneous fission (SF). The nuclides that undergo spontaneous fission also are subject to alpha decay. The alpha decay serves as an important tool to study about the properties of super heavy nuclei. Here the alpha decay half-life times of super heavy isotopes of Rutherfordium and Seaborgium have been predicted by implementing Cubic plus Yukawa plus Exponential (CYE) model and the results are compared with the theoretical Viola-Seaborg-Sobiczewski (VSS) relation, calculated Spontaneous Fission alpha decay half-life times and also with the available experimental values.**

***Keywords* - Alpha Decay, Half Life, Spontaneous Fission, Super heavy nuclei.**

I. INTRODUCTION

The properties of super heavy elements are studied through their decay. The two dominant modes of decay of SHN are alpha decay and spontaneous fission. Alpha decay plays a vital role in the detection of SHN and it forms the experimental signatures for the formation of SHN. In 1928, Gamow, Gurney and Condon [1, 2] formulated the theory of α-decay. With this as basis, various models such as Generalised Liquid Drop Model(GLDM) [3], Viola-Seaborg-Sobiczewski (VSS) [4] predicts the properties of super heavy nuclei. One such model is Cubic plus Yukawa plus Exponential model, which is successful in producing the alpha-decay half-lives.

In this work, description of CYE model is given in section-II. In section III Spontaneous Fission half life time formalism is given. Alpha decay half life time values calculated by CYE model are compared with the half-lives of Viola-Seaborg-Sobiczewski (VSS), calculated spontaneous fission half-lives and also with the available experimental values in the section IV. The results and discussion is provided in section V and finally section VI serves the conclusion part of this work.

II. Cubic plus Yukawa plus Exponential (CYE) model

In this work, to study the decay properties we have used a realistic model called as CYE model [5]. We use a cubic potential in the pre-scission region connected by Coulomb plus Yukawa plus Exponential potential in the post scission region. The alpha particle preexists within the nucleus at a certain distance from the nucleus, the potential encountered by the alpha particle is purely coulomb. This potential as a function of r which is the centre of mass distance of the two fragments for the post scission region is given by

$$V(r) = \frac{Z_d Z_e e^2}{r^2} + V_n(r) - Q \qquad r < r_t \qquad (1)$$

where Q represents the decay energy of the nuclei. Half-life time of the nucleus is calculated using the formula

$$T = \frac{1.423 \times 10^{-21}(1+\exp K)}{E_v} \qquad (2)$$

Here E_v is the Zero point vibration energy.

III. Spontaneous Fission Half Life Time

Spontaneous Fission is calculated using the semi-empirical relation. Xu et.al [6]

$$\mathbf{T_{1/2}} = \exp\{2\pi\, [c_0 + c_1A + c_2Z^2 + c_3Z^4 + c_4(N-Z)^2 - (0.13323 \times \frac{Z^2}{A^{\frac{1}{3}}} - 11.69)]\} \qquad (3)$$

Where constants are, C_0=-195.09227, C_1=3.10156, C_2=-0.04386, C_3=1.4030*10^{-6}, C_4=-0.03199

IV Alpha Decay Half Lives

In the earlier work [7] the alpha decay life time of SHN are predicted using CYE model. Here the half life time values of Rutherfordium and Seaborgium isotopes are calculated using CYE model and Spontaneous Fission formalism. The results are compared with the Viola-Seaborg-Sobiczewski formalism and also with the available experimental values and are recorded in Table 1 & 2. Figure 1 and 2 shows the comparative plot between theoretical alpha decay half life time values and experimental values.

Table 1: The calculated half-lives using CYE Model and Spontaneous Fission using semi-empirical formula for Rutherfordium (Rf) isotopes are compared with the VSS formalism and also with available experimental values.

Parent Nucleus	Q (MeV)	Log $T_{1/2}$(s)			
		This work CYE Model	SF[8]	VSS[4]	Expt.[8]
^{256}Rf	8.961	0.72	0.9884	-0.0574	-2.1938
^{257}Rf	9.127	0.17	0.1881	0.5082	0.6720
^{258}Rf	9.288	-0.34	0.4332	-1.0325	-1.8326
^{259}Rf	9.191	-0.06	0.8761	0.3191	0.5051
^{260}Rf	8.967	0.62	1.1401	-0.0755	3.1003
^{261}Rf	8.741	1.34	1.2258	1.6961	-
^{262}Rf	8.477	2.23	1.1325	1.4892	0.36172

Table 2: The calculated half-lives using CYE Model and Spontaneous Fission using semi-empirical formula for Seaborgium (Sg) isotopes are compared with the VSS formalism and also with available experimental values.

Parent Nucleus	Q (MeV)	Log $T_{1/2}$(s)			
		This work CYE Model	SF[8]	VSS[4]	Expt.[8]
^{260}Sg	10.012	-1.70	-2.6746	-2.3719	-2.4436
^{261}Sg	9.787	-1.09	-1.8601	-0.7013	-0.6382
^{262}Sg	9.693	-0.84	-1.2245	-1.5055	-2.1611
^{263}Sg	9.405	0.00	-0.7675	0.3769	-
^{264}Sg	9.204	0.60	-0.4893	-0.0958	3.3463
^{265}Sg	8.921	1.49	-0.3897	1.8409	-
^{266}Sg	8.613	2.51	-0.4687	1.7682	1.322

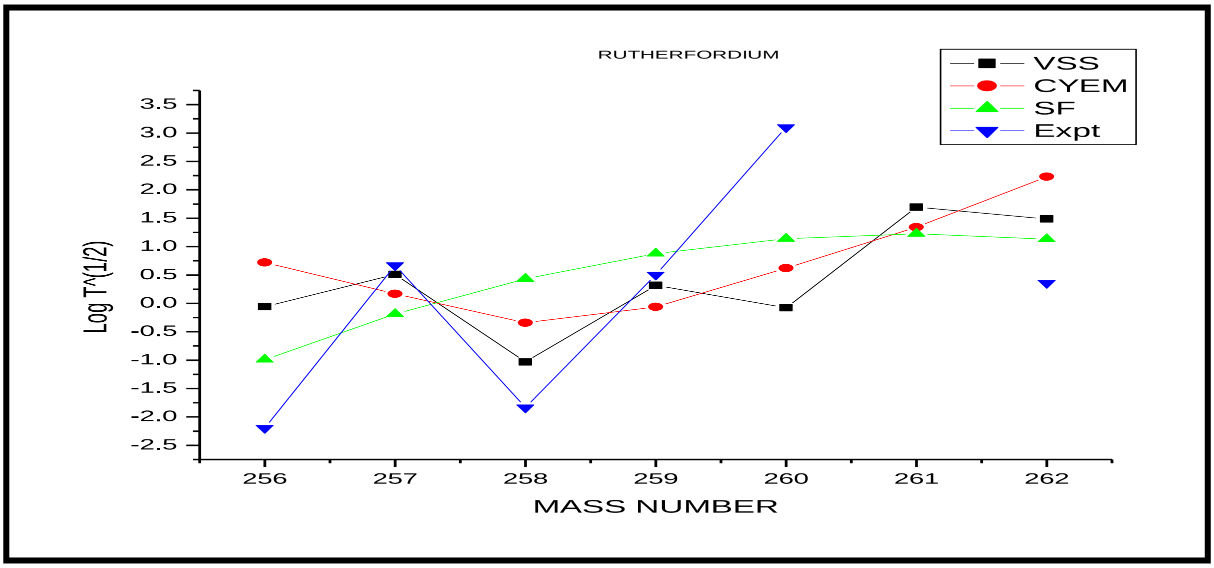

Figure 1 gives the plot of comparison of theoretical alpha decay half life time values with the experimental values.

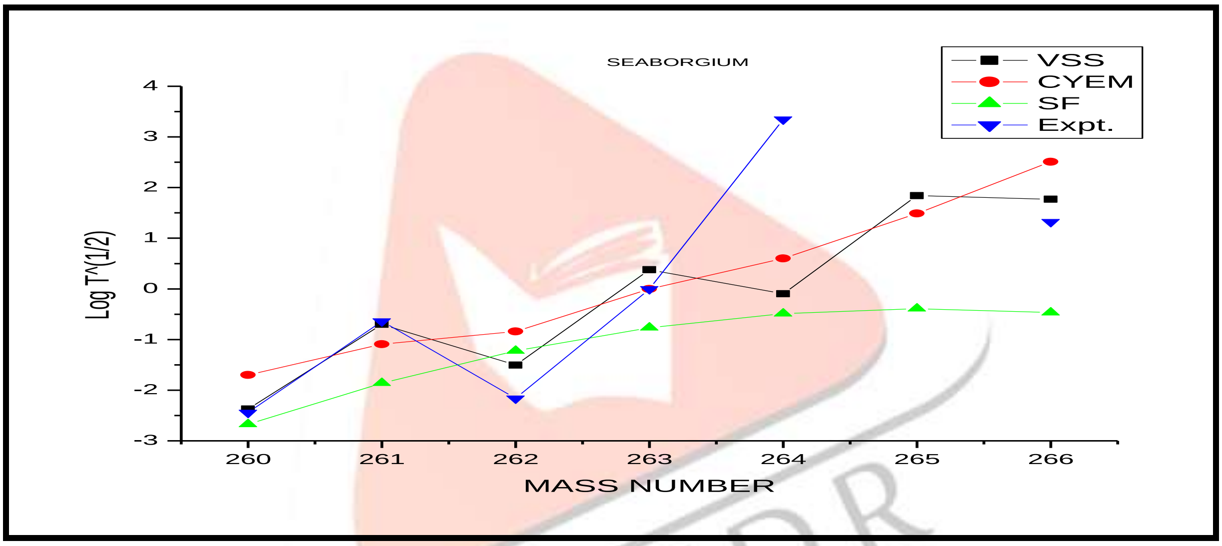

Figure 2 gives the plot of comparison of theoretical alpha decay half life time values with the experimental values.

V. Results and discussion

The Alpha decay half lives calculated using the CYE model and also the half lives due to Spontaneous Fission for the super heavy nuclei Rutherfordium and Seaborgium with Z = 104 and Z=106 are compared with experimental half-lives and recorded in Table 1 and 2. The table values agree fairly well with the experimental values. A few discrepancy in the value may be due to non-incorporation of deformation parameters [9]. Figure 1 and 2 shows the comparative study of alpha decay half life time and mass number. It also predicts that any isotopes of super heavy nucleus Rutherfordium and Seaborgium lies within the parabola of log $T_{1/2}$ Vs mass number plot has greater half-life time value for spontaneous fission than alpha decay and these can be identified in the laboratory via alpha decay.

VI. Conclusion

The Alpha decay and spontaneous half-lives of the super heavy nuclei Rutherfordium and Seaborgium (Z = 104 and Z=106) are computed using CYE Model and semi-empirical mass formula of Spontaneous Fission. From this work it is inferred that any isotopes of super heavy nuclei, which have more half-life for spontaneous fission compared to alpha decay, can be identified by the presence of alpha particle and it confirms the existence of long lived super heavy nuclei [10]. Finally this work presumes that the alpha decay comprise of favored isotopes of super heavy nuclei which may be a guide for future experiments.

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