A simplistic approach to study the alpha decay chain of $Z = 120$ isotopes within $A = 298 - 308$

G. Naveya[1], A. Stephen[1],* and S.I.A. Philominraj[2]
[1]Department of Nuclear Physics, University of Madras, Guindy Campus, Chennai-600025, INDIA and
[2]Department of Physics, Madras Christian College, Chennai-600059, INDIA

Introduction

A simplistic approach to evaluate alpha decay half lives of superheavy elements is presented in the recent work [1] and later the same approach is used to study the cluster emission ^{8}Be and ^{14}C [2], wherein the theoretical values and experimental values were in good agreement. The present work deals with the alpha decay chain of $Z = 120$ superheavy element. The interest in this particular superheavy nucleus is due to the recent experimental efforts to synthesise the isotope $^{299}120$ in a fusion reaction at the velocity filter SHIP (GSI Darmstadt) [3]. The current study focuses on even isotopes.

Present Framework

The present work is a theoretical evaluation of half lives for alpha decay, without taking into account the different forms of potentials used by different authors. Quantum mechanical tunneling is considered as usual, but instead of solving the barrier penetration integral, the area of the barrier is taken into account. The penetration integral involves momentum and displacement of cluster. The present approach is based on the assumption that the area of the momentum and displacement curve needs to be approximately equivalent to the penetration integral.

As the cluster emerges out of the daughter nucleus, the momentum will be proportional to $[V(r_t) - Q]^{1/2}$ where r_t is the touching distance of daughter and cluster, $V(r_t)$ is the corresponding Coulomb potential and Q is the kinetic energy of emerging cluster. When the cluster has emerged quite far away from the daughter , the potential becomes zero at the distance r_b. Here $(r_b - r_t)$ is the width of the barrier. Thus we have

$$\text{Penetration integral} \propto \sqrt{V(r_t) - Q}\ (r_b - r_t)$$

Using an approach similar to that of Gamow,

$$\log T_{\frac{1}{2}} \propto [V(r_t) - Q]^{1/2}\ (r_b - r_t) \quad (1)$$

By straight line fitting with alpha decay half lives of known superheavy elements, it is found that [1]

$$\log T_{\frac{1}{2}} = 0.1775[V(r_t) - Q]^{1/2}(r_b - r_t) - 17.8 \quad (2)$$

where $T_{\frac{1}{2}}$ is the half life of alpha emission in seconds. Also

$$V(r_t) = \frac{1.44\ Z_1 Z_2}{r_t} \quad \text{and} \quad r_b = \frac{1.44\ Z_1 Z_2}{Q}$$

where Z_1 corresponds to that of cluster and Z_2 corresponds to that of daughter nucleus and r_t is the touching distance of daughter and cluster being emitted with radius constant 1.26 fm, $V(r_t)$ being in MeV. Here, r_b corresponds to the outer turning point where potential is zero with Q in MeV. Equation (2) represents a straight line, which can readily be used for evaluation of decay rates of superheavy nuclei.

The calculated alpha decay half lives of the present work is reported in the table and is compared with Universal Decay Law(UDL) [4], Viola Seaborg Formula (VS) [5] [6], and Royer's Formula [7] . The spontaneous fission half life is also evaluated to predict the possible mode of decay using Xu et. al [8].

*Electronic address: stephen_arum@hotmail.com

TABLE I: Alpha decay chains from even istopes of $Z = 120$ and onset of spontaneous fission

Parent	Q (MeV)	$log_{10}T^{SF}_{1/2}$	$log_{10}T^{\alpha}_{1/2}$			($T_{1/2}$in secs)	Mode
		Xu	present	UDL	VS	Royer	
$^{298}120$	13.007	14.4905	-5.38045	-5.48973	-5.002	-5.44885	α
$^{294}118$	12.199	8.47973	-4.23198	-4.27579	-3.85121	-4.28824	α
$^{290}116$	11.085	3.80373	-2.16807	-2.14373	-1.84963	-2.26167	α
$^{286}114$	9.970	0.374951	0.36413	0.336791	0.471702	0.095124	α/SF
$^{282}112$	10.141	-1.89272	-0.768116	-0.879758	-0.648693	-1.03128	SF
$^{300}120$	13.319	12.5628	-5.99083	-6.18224	-5.61725	-6.10748	α
$^{296}118$	11.752	6.52489	-3.28023	-3.23509	-2.853	-3.31529	α
$^{292}116$	11.127	1.82165	-2.31216	-2.28627	-1.95277	-2.40302	α
$^{288}114$	9.645	-1.63451	1.36194	1.32075	1.41619	1.01508	SF
$^{302}120$	12.890	9.9216	-5.22387	-5.29912	-4.76554	-5.28308	α
$^{298}118$	12.183	3.85665	-4.26846	-4.30175	-3.81643	-4.3265	α
$^{294}116$	10.665	-0.873791	-1.13587	-1.06263	-0.785016	-1.2575	α
$^{290}114$	9.520	-4.35729	1.73877	1.69375	1.79227	1.35931	SF
$^{304}120$	12.763	6.56723	-5.00975	-5.05093	-4.5052	-5.05625	α
$^{300}118$	11.956	0.475263	-3.81168	-3.79495	-3.3155	-3.85619	α
$^{296}116$	10.893	-4.28234	-1.78662	-1.7234	-1.37059	-1.88686	SF
$^{306}120$	13.788	2.49992	-6.89906	-7.22748	-7.22748	-7.22748	α
$^{302}118$	12.041	-3.61905	-4.03311	-4.02952	-3.50473	-4.08382	α
$^{298}116$	10.770	-8.40377	-1.49802	-1.41748	-1.057	-1.60569	SF
$^{308}120$	12.966	-2.28013	-5.46908	-5.5583	-4.9195	-5.54707	α
$^{304}118$	13.122	-8.42604	-6.20809	-6.47174	-5.74854	-6.38967	SF

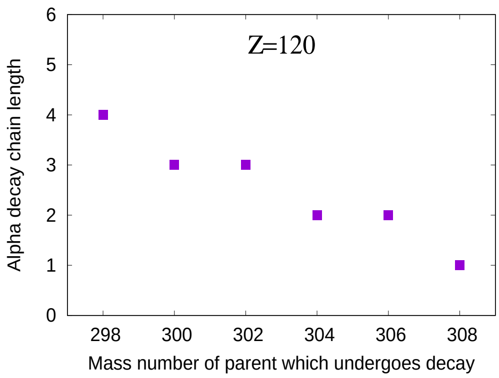

FIG. 1: Alpha decay chain length before onset of spontaneous fission

Conclusion

The calcuated half lives using present framework are in good agreement with the values from other phenomological formulae. The number of decays in the decay chains along with the Q values will be the unique signature associated with each of the isotopes. The isotopes when synthesized will decay rapidly via alpha chains and eventually will stop with a spontaneous fission. We hope that the results of our work will be of help for ongoing and future experiments associated with synthesis and identification of $Z = 120$ isotopes.

References

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