https://doi.org/10.15407/ujpe69.3.158

G.M. CARMEL VIGILA BAI,[1] V.S. AJITHRA [2, 3]

[1] Department of Physics, Government Arts and Science College
(Konam, Nagercoil-629 004, Tamilnadu, India; e-mail: gmcarmelvb@gmail.com)

[2] Department of Physics, Rani Anna Government College for Women
(Tirunelveli-08; e-mail: ajithra1994vs@gmail.com)

[3] Affiliated to Manonmaniam Sundaranar University, Abhishekapatti
(Tirunelveli-12, Tamilnadu, India)

PREDICTIONS FOR THE ALPHA DECAY OF $Z = 127$–138 SUPER HEAVY NUCLEI USING THE CYE MODEL

In recent years, the synthesis and identification of Superheavy elements have been of a great interest in the area of both experimental and theoretical nuclear physics. Using the CYE model, the alpha decay, cluster decay, and spontaneous fission in the heavy and superheavy nuclei have been studied. In the current work, we will investigate the α decay and obtain cluster decay half lifetimes in the interval Z = 127–138 and the spontaneous fission half lifetimes using the two-sphere approximation and will compare the results with the other theoretical values and the semiempirical formula by Xu et al. We believe that the predicted decay half-lifetimes are valuable for future tests, because they are in a good agreement with other theoretical formalisms.

Keywords: CYE model, alpha decay, superheavy nuclei, cluster, spontaneous fission, half-life time.

1. Introduction

Gamow identified shortly the decay as a quantum tunneling process, after it was identified by Rutherford and Geiger in 1928 [1, 2]. One of the key decay modes for describing the nuclear structure is the alpha decay which is successfully explainrd by quantum theory. For the computation and prediction of the α decay half lifetime, numerous theoretical and empirical models have been created since the time of Gamow, varying in accuracy and sophistication [3–12]. Wentzel–Kramers–Brillouin (WKB) approximation theory was used by A. Zdeb *et al.*, [13], to establish a straightforward formula for α decay half lifetimes. Rose and Jones *et al.* reported on the discovery of the radioactive decay of heavy nuclei by the emission of $^{14}_{6}$C. Superheavy elements have been discovered at the Lawrence Berkeley National Laboratory. Various theoretical models have been developed to study the decay properties of Superheavy elements, and those results have been confirmed by Gales *et al.*, and S.B. Price, [13 ,14]. In earlier work, the characteriistics of alpha decay, cluster decay, and spontaneous fission for super heavy nuclei have calculated using the CYE model [15, 16, 17]. We have already studied the decay properties of α decay for even nuclei (Z = 128, 130, 132, 134, 136, 138, 140, 142 and 144) [18, 19]. In the current work, we used the Cubic Plus Yukawa Plus Exponential Model in tthe wo-sphere approximation to examine the alpha decay and cluster decay characteristics of several isotopes of superheavy nuclei, Z = 127–138. The alpha and Spontaneous fission decay properties of various isotopes of SHE Z = 127–130 for different Q values have been studied using the CYE model. (Santhosh and Nithya, 2017; Santhosh and Priyanka, 2017) [20, 21] studied the alpha decay and cluster emission at Z = 110, 122, 126, 128 of parent nuclei and suggested $N = 184$ and $N = 202$. In the parent nuclei with $Z = 130$ and $Z = 138$ that we are currently surveying, we find additional shell closures at $N = 172$, 184, and 198 for a new neutron magic number. Hence,

Citation: Carmel Vigila Bai G.M., Ajithra V.S. Predictions for the alpha decay of Z = 127–138 super heavy nuclei using the CYE model. *Ukr. J. Phys.* **69**, No. 3, 158 (2024). https://doi.org/10.15407/ujpe69.3.158.

Цитування: Кармел Віджіла Бай Г.М., Аджітра В.С. Передбачення щодо альфа-розпаду надважких ядер із Z = 127–138 на основі CYE моделі. *Укр. фіз. журн.* **69**, №3, 158 (2024).

N = 172, 184, 198, 228, and 238 are likely to be the neutron magic numbers which have been previously reported for different relativistic mean field parametrization (Gambhir *et al.*, 2009; Bhuyan and Patra, 2012) [22, 23]. For a theoretical comparison, the alpha decay, cluster decay, and the spontaneous fission were compared with the CPP-ITM (Cubic Plus Proximity Potential with Improved Transfer Matrix) model, the UDL (universal decay law), the Royer analytic formula, Viola-Seaborg semiempirical formula (VSS), Shell-effect-dependent formula of Santhosh *et al.*, and Semiempirical formula by Xu *et al.* The results of current model's predictions with that of other models are quite consistent. We hope for that this study will be very useful for the future experimental investigations in this field.

2. Cubic Plus Yukawa Plus Exponential Model

In order to study the decay properties of Superheavy elements (SHE), we have used a realistic model [24], called as CYE model, in which we use a cubic potential in the pre-scission region which is connected by a Yukawa plus Exponential potential in the post scission region. Here, the zero-point vibration energy is explicitly included without violating the conservation of energy. The alpha particle pre-exists within the nucleus at a certain distance from the nucleus and the potential encountered by this alpha particle is a purely Coulomb one. This potential as a function of r which is the center of mass distance of the two fragments for the post scission region is given by,

$$V(r) = \frac{Z_1 Z_2 e^2}{r} + V_n(r) - Q; \quad r \geq r_t,$$

where, $V_n(r)$ is the nuclear interaction energy and written in the form

$$V_n(r) = -D\left[F + \frac{r - r_t}{a}\right]\frac{r_t}{r}\exp\left[\frac{r_t - r}{a}\right],$$

and $r_t = R_1 + R_2$ is the sum of their equivalent sharp surface radii. The depth constant D and the constant F.

The shape of the potential barrier in the overlapping region which connects the ground-state and the contact-point is approximated by a third order polynomial in r suggested by Ni_x having the form

$$V(r) = -E_v + [V(r_t) + E_v]\left\{s_1\left[\frac{r - r_i}{r_t - r_i}\right]^2 - s_2\left[\frac{r - r_i}{r_t - r_i}\right]^2\right\}; \quad r_i \leq r \leq r_t,$$

where r_i is the distance between the centers of mass of two portions of a parent nucleus cut by a planar section into two pieces with volume asymmetry of the decay.

Let a planar section cut the parent nucleus into two unequal portions with the masses of the heavy and light nuclei of the decay. If h_1 and h_2 are the heights of the heavy and light segments and R_0 is the radius of the parent nucleus, then

$$r_i = \frac{3}{4}\left[\frac{h_1^2}{R_0 + h_1} + \frac{h_2^2}{R_0 + h_2}\right].$$

For calculating the zero – point vibration energy E_v,

$$E_v = \frac{\pi\hbar}{2}\left[\frac{\left(\frac{2Q}{\mu}\right)^{1/2}}{(C_1 + C_2)}\right].$$

The central radii C_1 and C_2 of the fragments are given by

$$C_i = 1.18\,A^{1/3} - 0.48 \quad (i = 1, 2)$$

and

$$\mu = \frac{m_1 m_2}{m_1 + m_2},$$

where μ is the reduced mass of the system and m is the mass of the nucleon.

Half-life time value is calculated by using the formula $T = \frac{1.433\times10^{-21}(1+\exp K)}{E_v}$.

3. Results and Discussion

In this study, we used our Cubic plus Yukawa plus Exponential Model in a two-sphere approximation (WOD), to determine the alpha decay half lifetimes, cluster decay and spontaneous fission for various isotopes of Superheavy nuclei. The results are compared with the (CPP-ITM) model of G. Naveya *et al.*, [25, 26], the Universal Decay Law (UDL) of Qi *et al.*, [27,

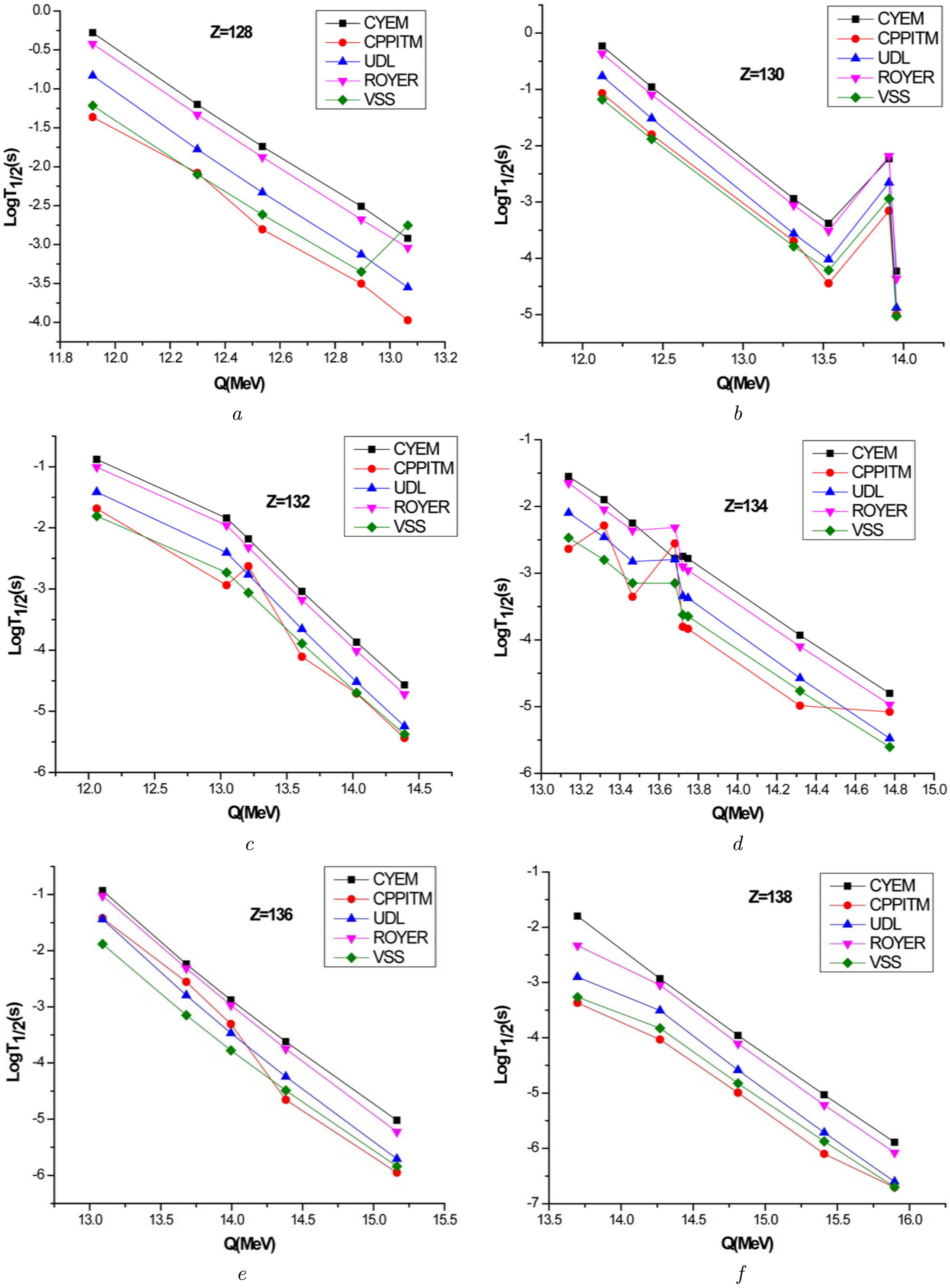


Fig. 1. Shows the comparison plot for the calculated logarithmic values of half lifetime of alpha decay without deformation Vs. Q value(MeV) for $Z = 128$, 130, 132, 136 and 138 even nucleus

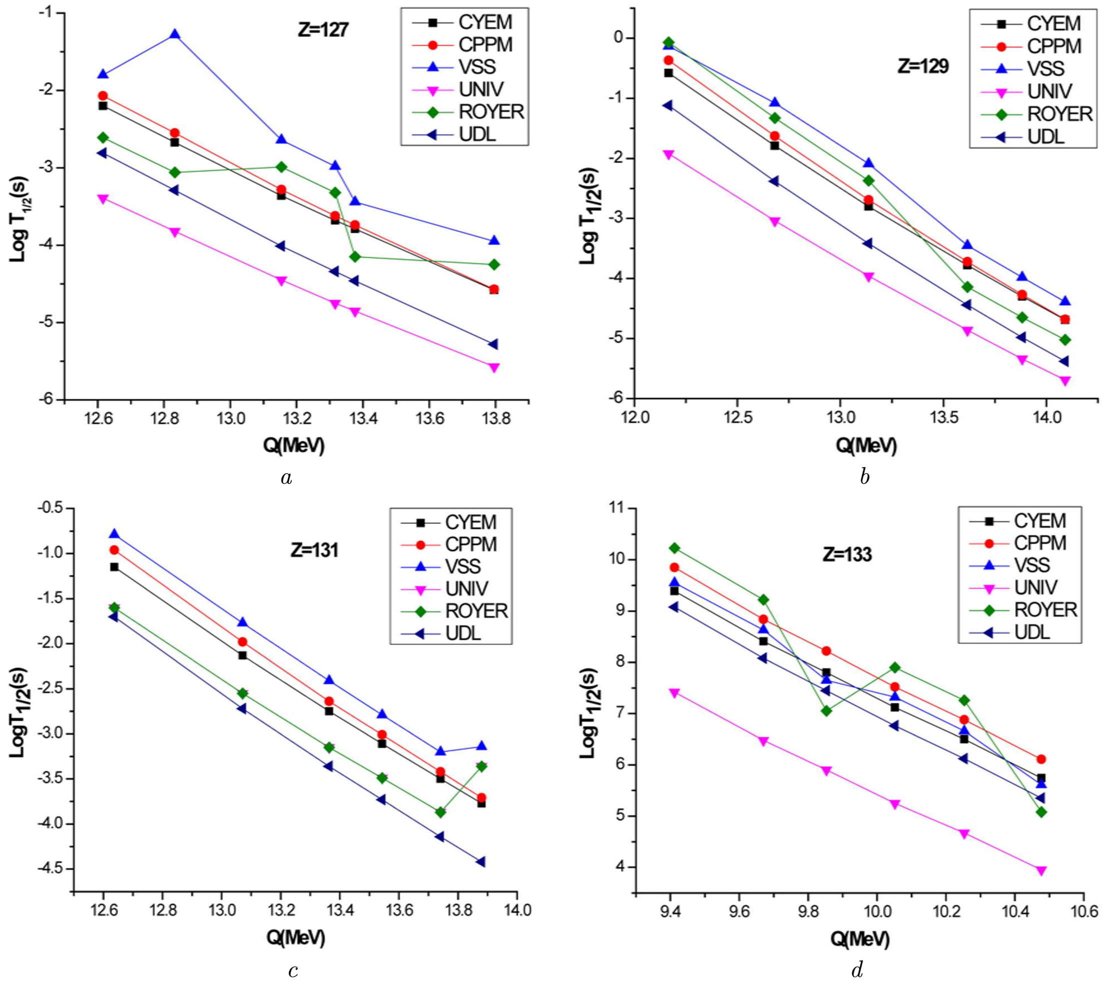


Fig. 2. Shows the comparison plot for the calculated logarithmic values of half lifetime of alpha decay without deformation Vs. Q value (MeV) for $Z = 127$, 131 and 133 odd nucleus

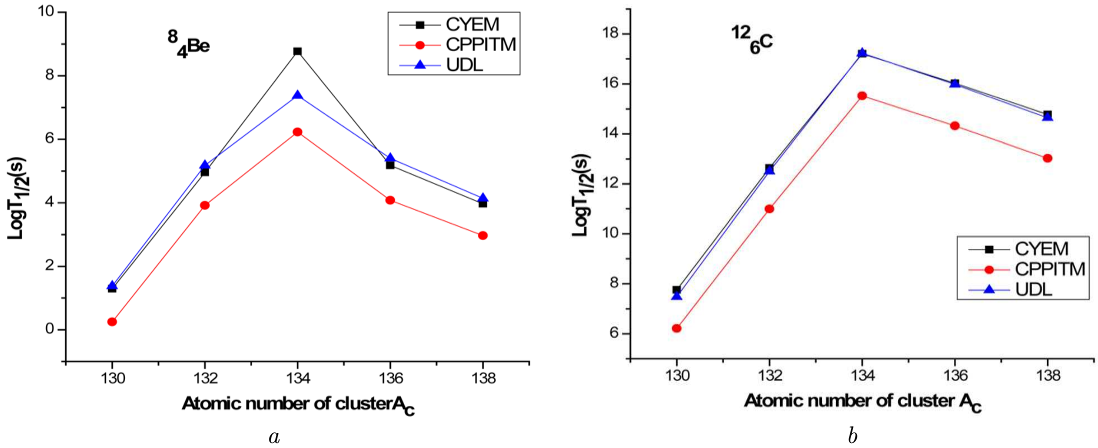
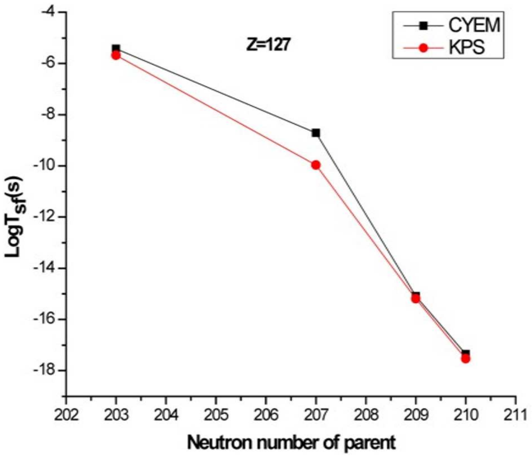
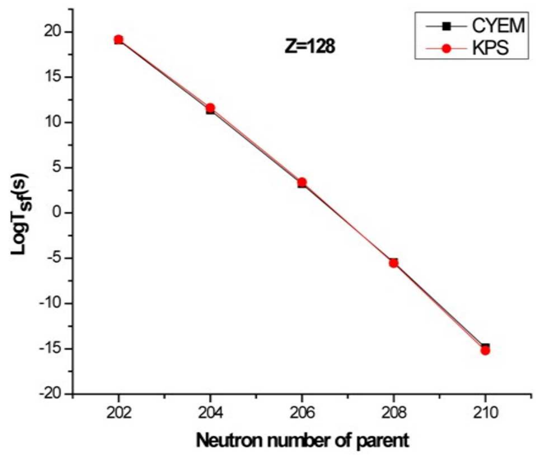


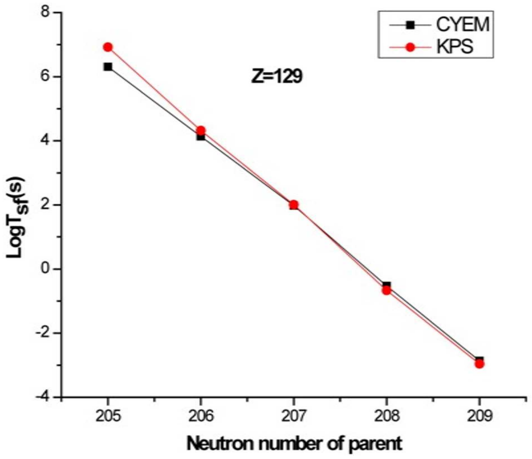
Fig. 3. Shows the comparison plot for the Q-value and the half lifetimes for cluster emission of $^{8}_{4}$Be, $^{12}_{6}$C for $Z = 130$–138 even-even isotopes



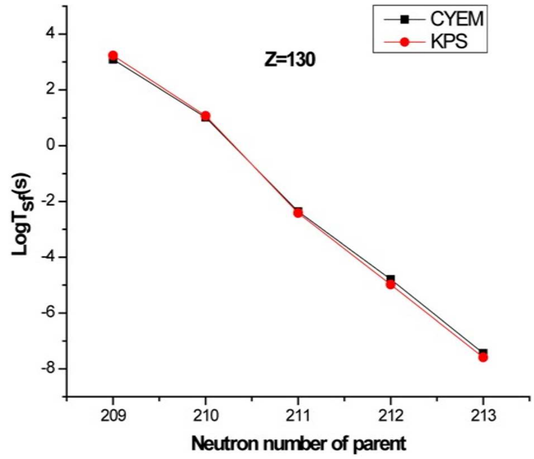
a



b

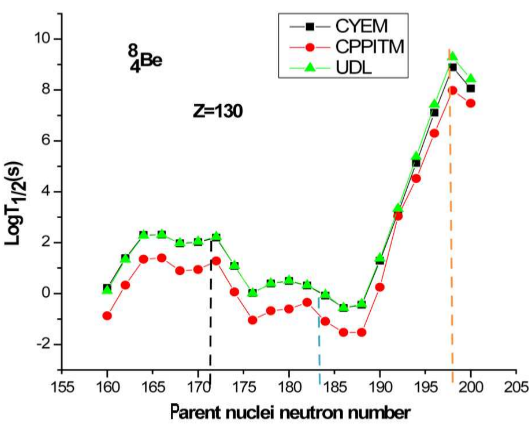


c

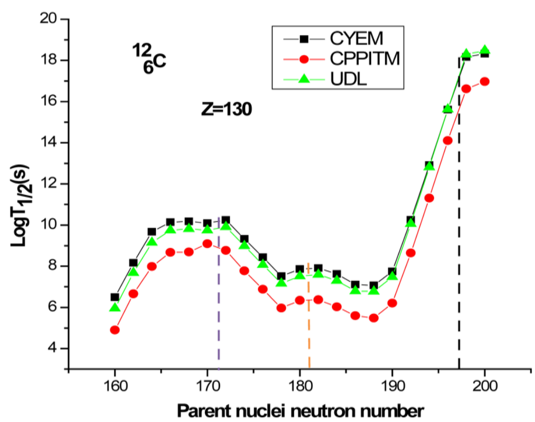


d

Fig. 4. Shows the comparison plot of SF half lifetimes for the Neutron number of parent nuclei versus Log$T_{1/2}(s)$

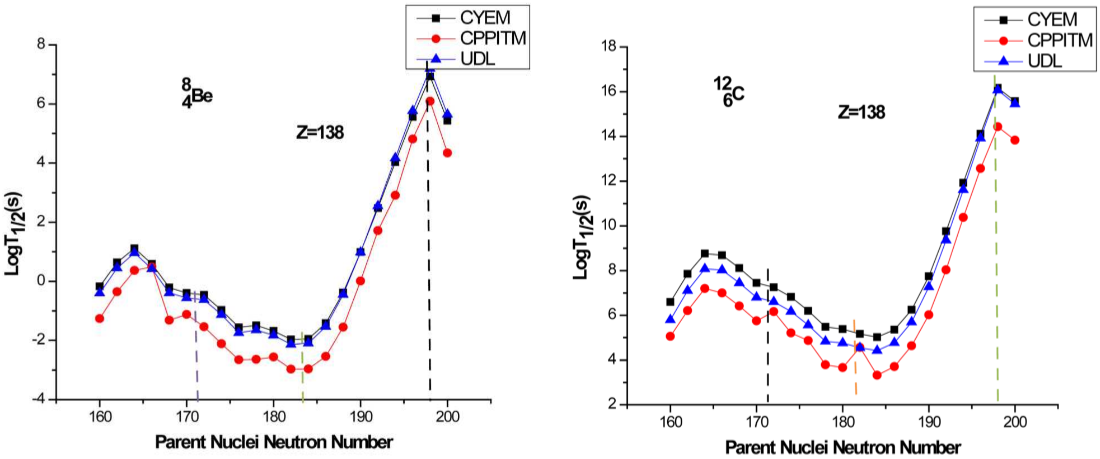


a



b

Fig. 5. Half lifetimes for $^{8}_{4}$Be and $^{12}_{6}$C emission against neutron number of daughter nuclei for $Z = 130$



a *b*

Fig. 6. Half lifetimes for $^{8}_{4}$Be and $^{12}_{6}$C emission against neutron number of parent nuclei for $Z = 138$

28] the Royer Analytical Formula [10] and the Viola-Seaborg Semiempirical Formula (VSS)[29], (CPPM) model of K.P. Santhosh *et al.*, [30], (UNIV) D.N. Poenaru *et al.*, [31], D.N. Poenaru *et al.*, [32] for the alpha emission and cluster emission. Since spontaneous fission is complex, spontaneous fission half lifetime using the new shell-effect-dependent formula by Santhosh *et al.*, [33, 34] was obtained which provides a good description of SF half lifetimes. We have compared the calculated half life values to other theoretical values that are currently accessible in Table 1. Binding energy from the WS4 mass table is used to compute Q-values [35]. Table 2 shows the comparison of alpha decay half lifetime values for different isotopes of Superheavy nuclei $Z = 127$, 129, 131 & 133 odd-odd isotopes using the CYE Model with the available theoretical models. The Q-value and the half lifetimes for cluster emission of $^{8}_{4}$Be and $^{12}_{6}$C for $Z = 130$–138 even even isotopes in Table 3. In Table 4, several SHE $Z = 127$–130 isotopes alpha decay and spontaneous fission decay characteristics over a range of Q values have been investigated using the CYE model. The predictions of the present model and other models are highly consistent with each other. Figures 1 and 2 show the variance in the logarithmic alpha decay half lifetimes with Q-values for different superheavy nuclear isotopes. Figures 3 and 4 show the comparison plot for the Q-value and the half lifetimes for cluster emission of $^{8}_{4}$Be and $^{12}_{6}$C for $Z = 130$–138 even even isotopes. In Fig. 4, the half-lifetime obtained with the present calculation is plotted with respect to the parent nuclei neutron number. Figures 5 and 6 show the parent nuclei of $Z = 130$ and $Z = 138$ brings out more shell closures at $N = 172$, 184 and 198, such a consistent trend seen is the evidence of new neutron magic numbers. Additionally, the Geiger–Nuttall law plot for decay modes of $Z = 131$ isotope is represented in Fig. 6, it shows the linearrelationship between $1/\sqrt{Q}$ (MeV)$^{-1/2}$ versus $\text{Log}\, T_{1/2}(\text{s})$, and the straight line indicates that the model predictions are correct. The achieved values exhibit excellent agreement with other values. Theoretical predictions made here will undoubtedly provide a useful direction for upcoming experimental work on the synthesis and/or identification of these superheavy isotopes.

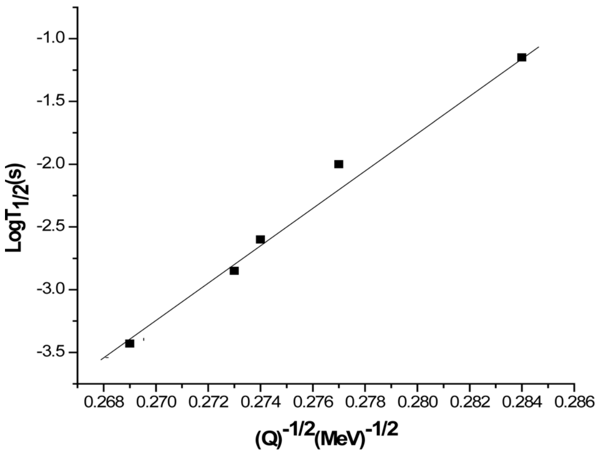


Fig. 7. Geiger-Nuttall law curve for decay modes of $Z = 131$ isotope

Table 1. **Comparison of alpha decay half lifetime values for different isotopes of Superheavy nuclei Z = 128, 130, 132, 134, 136 and 138 even-even isotopes using life CYE Model with the available theoretical models**

Parent nuclei	Q_α (MeV) [35]	Log $T_{1/2}(s)$				
		CYEM [calcu lated]	CPP-ITM [25]	UDL [27]	ROYER [10]	VSS [29]
$^{330}128$	12.8957	–2.51	–3.5035	–3.1280	–2.6766	–3.3501
$^{332}128$	13.0651	–2.92	–3.9727	–3.5498	–3.0415	–3.7528
$^{334}128$	12.5360	–1.74	–2.8055	–2.3313	–1.8776	–2.6143
$^{336}128$	12.2992	–1.20	–2.0786	–1.7764	–1.3325	–2.0993
$^{338}128$	11.9186	–0.28	–1.3629	–0.8299	–0.4225	–1.2164
$^{334}130$	13.9555	–4.23	–5.0077	–4.8976	–4.3591	–5.0295
$^{336}130$	13.5338	–3.38	–4.4460	–4.0195	–3.5119	–4.2110
$^{338}130$	13.3156	–2.94	–3.6916	–3.5624	–3.0576	–3.7880
$^{340}130$	13.9096	–2.23	–3.1557	–2.6535	–2.1822	–2.9406
$^{342}130$	12.4306	–0.96	–1.8016	–1.5170	–1.0947	–1.8794
$^{344}130$	12.1234	–0.23	–1.0710	–0.7626	–0.3638	–1.1772
$^{338}132$	14.3920	–4.57	–5.4388	–5.2474	–4.7203	–5.3744
$^{340}132$	14.0282	–3.87	–4.7080	–4.5204	–4.0139	–4.6980
$^{342}132$	13.6154	–3.64	–4.1100	–3.6546	–3.1782	–3.8912
$^{344}132$	13.2101	–2.18	–2.6275	–2.7644	–2.3199	–3.0616
$^{346}132$	13.0448	–1.84	–2.9381	–2.4066	–1.9585	–2.7319
$^{348}132$	12.6237	–0.88	–1.6865	–1.4147	–1.0057	–1.8068
$^{342}134$	14.7738	–4.80	–5.0788	–5.4735	–4.9684	–5.6028
$^{344}134$	14.3175	–3.93	–4.9848	–4.5723	–4.0993	–4.7630
$^{346}134$	13.7477	–2.78	–3.8349	–3.3746	–2.9538	–3.6450
$^{348}134$	13.7206	–2.75	–3.8040	–3.3442	–2.875	–3.6227
$^{350}134$	13.3200	–1.90	–2.2860	–2.4613	–2.0460	–2.8001
$^{352}134$	13.4650	–2.25	–3.3548	–2.8260	–2.3586	–3.1486
$^{354}134$	13.1393	–1.54	–2.6380	–2.0952	–1.6494	–2.4688
$^{356}134$	13.6801	–2.78	–2.5548	–2.7961	–2.3145	–3.1491
$^{346}136$	15.1645	–5.02	–5.9496	–5.7084	–5.2271	–5.8392
$^{348}136$	14.5966	–3.95	–4.9601	–4.6012	–4.1654	–4.8063
$^{350}136$	14.8634	–4.51	–5.3275	–5.1739	–4.6719	–5.3499
$^{352}136$	14.3222	–3.47	–4.0012	–4.0874	–3.6299	–4.3365
$^{354}136$	14.3825	–3.62	–4.6576	–4.2446	–3.7489	–4.4901
$^{356}136$	13.9982	–2.84	–3.4155	–3.4477	–2.9775	–3.7485
$^{358}136$	13.9953	–2.88	–3.3071	–3.4708	–2.9715	–3.7761
$^{360}136$	13.6801	–2.24	–2.5548	–2.7961	–2.3145	–3.1491
$^{362}136$	13.0905	–0.93	–1.4248	–1.4406	–1.0224	–1.8834
$^{364}136$	13.4369	–1.74	–2.7883	–2.2943	–1.7920	–2.6904
$^{366}136$	13.6884	–2.33	–3.3703	–2.9022	–2.3321	–3.2666
$^{350}138$	15.4215	–5.01	–5.9178	–5.6793	–5.2413	–5.8277
$^{352}138$	15.8961	–5.89	–6.7076	–6.6032	–6.0758	–6.7007
$^{354}138$	15.4086	–5.03	–6.1003	–5.7146	–5.2181	–5.8730
$^{356}138$	15.2294	–4.73	–5.7629	–5.3957	–4.8925	–5.5800
$^{358}138$	14.8104	–3.96	–4.9934	–4.5856	–4.1084	–4.8261
$^{360}138$	14.6735	–3.72	–4.6262	–4.3329	–3.8448	–4.5950
$^{362}138$	14.2704	–2.93	–4.0349	–3.5079	–3.0472	–3.8272
$^{364}138$	13.7956	–1.93	–2.8878	–2.4829	–2.0630	–2.8717
$^{366}138$	14.1862	–2.80	–3.8872	–3.3833	–2.8762	–3.7222
$^{368}138$	14.0109	–2.47	–3.4721	–3.0259	–2.5155	–3.3930
$^{370}138$	13.6986	–1.80	–3.3703	–2.9022	–2.3321	–3.2666

Table 2. **Comparison of alpha decay half lifetime values for different isotopes of Superheavy nuclei Z = 127, 129, 131 and 133 odd-odd isotopes using life CYE Model with the available theoretical models**

Parent nuclei	Q_α (MeV) [35]	Log $T_{1/2}(s)$					
		CYEM [calcu-lated]	CPPM [30]	VSS [29]	UNIV [31, 32]	ROYER [10]	UDL [27]
$^{320}127$	13.796	–4.58	–4.57	–3.95	–5.57	–4.25	–5.28
$^{321}127$	13.397	–3.77	–3.72	–3.49	–4.83	–4.12	–4.44
$^{322}127$	13.238	–3.45	–3.38	–2.81	–4.53	–3.08	–4.11
$^{323}127$	13.220	–3.43	–3.36	–3.12	–4.51	–3.79	–4.08
$^{324}127$	13.339	–3.70	–3.64	–3.02	–4.76	–3.33	–4.36
$^{325}127$	13.376	–3.79	–3.74	–3.44	–4.85	–4.15	–4.46
$^{326}127$	13.316	–3.68	–3.62	–2.98	–4.75	–3.32	–4.34
$^{327}127$	13.200	–3.45	–3.37	–3.08	–4.53	–3.81	–4.10
$^{328}127$	13.154	–3.36	–3.28	–2.64	–4.45	–2.99	–4.01
$^{329}127$	12.833	–2.67	–2.55	–1.28	–3.82	–3.06	–3.29
$^{330}127$	12.651	–2.27	–2.38	–1.54	–3.45	–1.85	–2.88
$^{331}127$	12.616	–2.20	–2.07	–1.80	–3.39	–2.61	–2.81
$^{326}129$	14.051	–4.59	–4.58	–3.97	–5.60	–4.23	–5.28
$^{327}129$	14.091	–4.69	–4.68	–4.39	–5.69	–5.02	–5.38
$^{328}129$	14.004	–4.53	–4.51	–3.88	–5.54	–4.17	–5.21
$^{329}129$	13.883	–4.30	–4.27	–3.98	–5.34	–4.65	–4.98
$^{330}129$	13.785	–4.12	–4.07	–3.44	–5.17	–3.74	–1.78
$^{331}129$	13.617	–3.78	–3.72	–3.45	–4.86	–4.14	–4.44
$^{332}129$	13.301	–3.12	–3.03	–2.44	–4.26	–2.71	–3.75
$^{333}129$	13.343	–3.23	–3.14	–2.87	–4.38	–3.61	–3.86
$^{334}129$	13.137	–2.80	–2.69	–2.09	–3.96	–2.37	–3.42
$^{335}129$	12.762	–1.96	–1.81	–1.60	–3.20	–2.38	–2.55
$^{336}129$	12.682	–1.79	–1.63	–1.08	–3.04	–1.33	–2.38
$^{337}129$	12.531	–1.45	–1.28	–1.07	–2.73	–1.89	–2.02
$^{338}129$	12.166	–0.58	–0.37	–0.13	–1.92	–0.07	–1.12
$^{334}131$	13.880	–3.77	–3.71	–3.14	–3.36	–3.36	–4.42
$^{335}131$	13.741	–3.50	–3.42	–3.20	–3.87	–3.87	–4.14
$^{336}131$	13.702	–3.43	–3.35	–2.78	–3.00	–3.00	–4.07
$^{337}131$	13.543	–3.11	–3.01	–2.79	–3.49	–3.49	–3.73
$^{338}131$	13.417	–2.85	–2.74	–2.18	–3.40	–3.40	–3.47
$^{339}131$	13.364	–2.75	–2.64	–2.41	–3.15	–3.15	–3.36
$^{340}131$	13.285	–2.60	–2.47	–1.90	–2.13	–2.13	–3.21
$^{341}131$	13.071	–2.13	–1.98	–1.77	–2.55	–2.55	–2.72
$^{342}131$	13.007	–2.00	–1.85	–1.29	–1.52	–1.52	–2.58
$^{343}131$	12.637	–1.15	–0.96	–0.79	–1.60	–1.60	–1.70
$^{329}133$	10.046	7.22	7.62	7.00	5.35	6.50	6.85
$^{330}133$	10.253	6.50	6.88	6.66	4.67	7.26	6.12
$^{331}133$	10.477	5.74	6.11	5.61	3.95	5.08	5.35
$^{332}133$	10.393	6.00	6.38	6.21	4.20	6.75	5.62
$^{323}133$	10.221	6.56	6.95	6.42	4.72	5.86	6.18
$^{334}133$	10.052	7.12	7.52	7.32	5.25	7.90	6.76
$^{335}133$	9.853	7.80	8.22	7.65	5.90	7.05	7.45
$^{336}133$	9.412	9.39	9.85	9.55	7.42	10.23	9.08
$^{337}133$	9.508	9.03	9.47	8.87	7.07	8.23	8.71
$^{338}133$	9.670	8.41	8.84	8.63	6.48	9.22	8.08
$^{339}133$	9.581	8.72	9.16	8.61	6.78	7.93	8.40

Table 3. **The Q-value and the half lifetimes for cluster emission of $^{8}_{4}$Be and $^{12}_{6}$C for $Z = 130$–138 even-even isotopes**

Parent nuclei	Q_{Be} (MeV) [35]	$\log T_{1/2}(s)$			Q_c (MeV) [35]	$\log T_{1/2}(s)$		
		CYEM [calculated]	CPP-ITM [26]	UDL [28]		CYEM [calculated]	CPP-ITM [26]	UDL [28]
$^{320}130$	34.69	1.29	0.25	1.38	54.93	7.75	6.21	7.48
$^{322}130$	33.37	3.18	3.04	3.34	52.98	10.26	8.64	10.07
$^{324}130$	32.08	5.13	4.52	5.38	51.03	12.91	11.31	12.82
$^{326}130$	30.85	7.11	6.30	7.43	49.15	15.61	14.11	15.63
$^{328}130$	29.80	8.89	7.98	9.29	47.46	18.17	16.62	18.30
$^{330}130$	30.23	8.06	7.48	8.43	47.30	18.33	16.97	18.48
$^{332}130$	30.65	7.26	6.78	7.62	47.27	18.29	16.74	18.43
$^{334}130$	29.86	8.59	7.58	8.99	47.10	18.47	17.27	18.64
$^{336}130$	28.90	10.30	9.32	10.76	45.85	20.46	19.60	20.72
$^{338}130$	27.89	12.20	11.36	12.74	44.38	22.92	21.28	23.27
$^{340}130$	26.86	14.25	13.86	14.87	42.85	25.63	24.17	26.09
$^{342}130$	25.82	16.45	16.13	17.15	41.30	28.53	26.89	29.11
$^{320}132$	36.59	–0.34	–1.13	–0.33	56.85	6.75	5.10	6.39
$^{322}132$	35.37	1.28	0.32	1.35	56.07	7.65	7.03	7.32
$^{324}132$	34.09	3.07	2.02	3.22	54.15	10.07	8.52	9.82
$^{326}132$	32.82	4.96	3.92	5.18	52.22	12.64	10.99	12.50
$^{328}132$	31.62	6.85	6.13	7.15	50.35	15.27	13.82	15.23
$^{330}132$	30.58	8.57	7.55	8.95	48.67	17.76	16.19	17.82
$^{332}132$	31.12	7.57	7.22	7.90	48.62	17.74	16.12	17.82
$^{334}132$	31.67	6.57	5.52	6.89	48.71	17.51	15.86	17.89
$^{336}132$	30.86	7.89	6.88	8.25	48.66	17.49	15.87	17.59
$^{338}132$	29.91	9.51	8.50	9.96	47.39	19.44	17.78	19.63
$^{340}132$	28.90	11.34	10.30	11.85	45.92	21.82	20.41	22.10
$^{342}132$	27.88	13.28	12.26	13.87	44.40	24.40	22.76	24.79
$^{320}134$	37.79	–0.94	–2.07	–0.99	58.47	6.18	5.39	5.74
$^{322}134$	37.18	–0.21	–1.13	–0.22	58.02	6.63	4.99	6.21
$^{324}134$	36.02	1.31	0.29	1.36	57.02	7.79	6.12	7.41
$^{326}134$	34.78	3.02	2.04	3.14	55.19	10.06	8.50	9.77
$^{328}134$	33.55	4.81	3.75	5.01	53.31	12.53	10.93	12.33
$^{330}134$	32.38	6.61	5.58	6.88	51.49	15.04	13.82	14.95
$^{332}134$	31.37	8.24	5.17	8.59	49.85	17.41	16.03	17.43
$^{334}134$	32.03	8.77	6.23	7.38	49.92	17.21	15.52	17.23
$^{336}134$	32.68	5.93	4.99	6.20	50.12	16.81	15.43	16.83
$^{338}134$	31.88	7.18	6.55	7.51	50.21	16.58	14.98	16.61
$^{340}134$	30.94	8.73	8.65	9.13	48.92	18.49	17.23	18.60
$^{342}134$	29.95	10.45	9.77	10.92	47.47	20.75	19.08	20.96
$^{320}136$	38.90	–1.40	–2.22	–1.50	60.02	5.72	4.01	5.19
$^{322}136$	38.59	–1.08	–2.24	–1.16	59.82	5.85	4.23	5.34
$^{324}136$	37.83	–0.16	–1.30	–0.19	59.18	6.53	5.28	6.05
$^{326}136$	36.71	1.28	0.26	1.31	57.99	7.90	6.29	7.48
$^{328}136$	35.52	2.90	2.05	2.99	56.24	10.04	8.34	9.70
$^{330}136$	34.34	4.58	3.70	4.75	54.43	12.37	11.54	12.13
$^{332}136$	33.22	6.26	5.19	6.51	52.68	14.74	13.20	14.61
$^{334}136$	32.24	7.80	6.70	8.11	51.09	16.99	15.61	16.95
$^{336}136$	33.01	6.47	5.38	6.74	51.28	16.61	14.89	16.56
$^{338}136$	33.78	5.18	4.08	5.40	51.60	16.03	14.32	15.98
$^{340}136$	33.00	6.35	5.30	6.63	51.83	15.60	14.35	15.55
$^{342}136$	32.10	7.78	6.75	8.13	50.57	17.40	15.82	17.43
$^{320}138$	40.12	–1.97	–2.97	–2.13	61.67	5.16	4.56	4.54
$^{322}138$	40.04	–1.95	–2.96	–2.09	61.70	5.02	3.32	4.42
$^{324}138$	39.56	–1.42	–2.54	–1.53	61.33	5.35	3.71	4.77
$^{326}138$	38.69	–0.38	–1.55	–0.45	60.50	6.24	4.63	5.69
$^{328}138$	37.60	0.99	0.01	0.98	59.18	7.74	6.02	7.27
$^{330}138$	36.47	2.48	1.72	2.55	57.50	9.76	8.03	9.36
$^{332}138$	35.35	4.03	2.91	4.17	55.78	11.92	10.38	11.62
$^{334}138$	34.29	5.56	4.81	5.77	54.11	14.12	12.56	13.02
$^{336}138$	33.38	6.93	6.09	7.20	52.61	16.17	14.43	16.07
$^{338}138$	34.29	5.43	4.34	5.65	52.96	15.57	13.83	15.45
$^{340}138$	35.21	3.97	2.97	4.14	53.44	14.78	13.02	14.64
$^{342}138$	34.51	4.97	3.97	5.18	53.85	14.10	12.36	13.95

Table 4. **The alpha and Spontaneous fission decay properties of various isotopes of SHE $Z = 127$–130 for different Q values**

Parent nuclei	Q_α (MeV) [35]	CYEM [calculated]		Ref. [33, 34]		Dominant decay modes
		Log$T_\alpha(s)$	Log$T_{sf}(s)$	Log$T_\alpha(s)$	Log$T_{sf}(s)$	
$^{330}127$	12.65	–2.27	–5.42	–2.38	–5.68	α
$^{332}127$	12.38	–1.48	–4.63	–1.50	–4.78	SF
$^{334}127$	12.12	–0.68	–8.71	–0.88	–9.97	SF
$^{336}127$	11.30	1.09	–15.09	1.11	–15.19	SF
$^{338}127$	10.60	3.16	–17.36	3.35	–17.53	SF
$^{330}128$	12.89	–3.42	19.08	–3.50	19.15	α
$^{332}128$	13.06	–3.89	11.34	–3.97	11.62	α
$^{334}128$	12.53	–2.64	3.21	–2.80	3.39	α
$^{336}128$	12.29	–2.01	–5.47	–2.07	–5.55	SF
$^{338}128$	11.91	–1.31	–14.89	–1.36	–15.21	SF
$^{334}129$	13.13	–2.80	6.31	–2.69	6.92	α
$^{335}129$	12.76	–1.96	4.14	–1.81	4.32	α
$^{336}129$	12.68	–1.79	1.98	–1.63	2.01	α
$^{337}129$	12.53	–1.45	–0.53	–1.28	–0.67	α
$^{338}129$	12.16	–0.58	–2.87	–0.37	–2.96	SF
$^{339}129$	11.89	0.28	–5.48	0.31	–5.64	SF
$^{339}130$	12.91	–1.76	3.09	–1.92	3.23	α
$^{340}130$	12.72	–1.34	1.01	–1.48	1.07	α
$^{341}130$	12.58	–1.02	–2.36	–1.13	–2.42	SF
$^{342}130$	12.47	–0.65	–4.79	–0.89	–4.98	SF
$^{343}130$	12.23	–0.19	–7.44	–0.29	–7.59	SF
$^{344}130$	12.07	0.10	–10.09	0.11	–10.26	SF

We have predicted the alpha decay half-lives, cluster decay and spontaneous fission half lifetimes in the isotopes 127–138 are studied using the CYE model. Alpha decay, cluster decay and spontaneous fission half lifetimes are compared with other theoretical models like CPP-ITM, CPPM, VSS, UDL, UNIV, KPS and analytical formula of Royer. The neutron shell closure at $N = 172$, 184 and 198 and is the signatures of magicity is presented. The theoretical predictions reported here will certainly have useful guidance for the future experimental efforts towards the synthesis and/or identification of these superheavy isotopes.

1. E. Rutherford, H. Geiger. The charge and nature of the α-particle. *Proc. R. Soc. London Ser. A* **81**, 162 (1908).
2. G.Z. Gamow. Zur quantentheorie des atomkernes. *Phys.* **51**, 204 (1928).
3. D.N. Basu. Role of effective interaction in nuclear disintegration processes. *Phys. Lett. B* **90**, 566 (2003).
4. Z. Ren, C. Xu, Z. Wang. New perspective on complex cluster radioactivity of heavy nuclei. *Phys. Rev. C* **70**, 034304 (2004).
5. G. Royer, R. Moustabchir. Light nucleus emission within a generalized liquid-drop model and quasimolecular shapes. *Nucl. Phys. A* **683**, 182 (2001).
6. G.L. Zhang, H.B. Zheng, W.W. Qu. Study of the univarsal function of nuclear proximity potential between α and nuclei from density-dependent nucleon-nucleon interaction. *Eur. Phys. J. A* **49**, 10 (2013).
7. Y.J. Yao, G.L. Zhang, W.W. Qu, J.Q. Qian. Comparative studies for different proximity potentials applied to α decay. *Eur. Phys. J. A* **51**, 122 (2015).
8. K. Varga, R.G. Lovas, R.J. Liotta. Absolute alpha decay width of ^{212}Po in a combined shell and cluster model. *Phys. Rev. Lett.* **69**, 37 (1992).
9. B. Buck, A.C. Merchant, S.M. Perez. Systematics of alpha-cluster states above double shell closures. *Phys. Rev. C* **51**, 559 (1995).
10. G. Royer. Alpha emission and spontaneous fission through quasi-molecular shapes. *J. Phys. G: Nucl. Part. Phys.* **26**, 1149 (2000).
11. Y.Z. Wang, S.J. Wang, Z.Y. Hou, J.Z. Gu. Systematic study of α-decay energies and half lifetimes of superheavy nuclei. *Phys. Rev. C* **92**, 064301 (2015).
12. P. Mohr. α-nucleus potentials, α-decay half-lives, and shell closures for superheavy nuclei. *Phys. Rev. C* **73**, 031301 (2006).
13. S. Gales, E. Hourani, M. Hussonnois, J.P. Schapira, L. Stab, M. Vergnes. Exotic nuclear decay of ^{23}Ra by emission of ^{14}C nuclei. *Phys. Rev. Lett.* **53**, 759 (1984).
14. P.B. Price, J.D. Stevenson, S.W. Barwick, H.L. Ravn. Discovery of radioactive decay of ^{222}Ra and ^{224}Ra by ^{14}C emission. *Phys. Rev. Lett.* **54**, 297 (1985).
15. G.M. Carmel Vigila Bai, J. Umai Parvathiy. Alpha decay properties of heavy and superheavy elements. *Pramana, J. Phys.* **84** (1), 113 (2015).
16. J. Umai Parvathy. *Properties of Superheavy Elements in Trans-Actinide Region.* Ph.D. thesis (Manonmanium sundaranar university, 2016).
17. G.M. Carmel Vigila Bai, R. Revathi. Competition between alpha decay, cluster decay and spontaneous fission in the Superheavy nuclei, $Z = 126$. *Math. Sci. Int. Res. J.* **7**, (2018).
18. G.M. Carmel Vigila Bai, V.S. Ajithra. Alpha decay chains of superheavy nuclei, $Z = 128$–138. In: *Proceedings of the International Conference on Advanced Research Trends in Material Science and Nanomaterials IVCARTMSN-2022 organised by Department of Physics Selvam Arts and Science college (Autonomous), Nammakal, May 24–5* (2022).
19. G.M. Carmel Vigila Bai, V.S. Ajithra. Alpha decay chains of superheavy nuclei, $Z = 140$–144. In: *Proceedings of the National seminar on Functional Materials and its Application NSFMA2022, organized by Department of Physics Muslim Arts College, Tiruvithancode, October 14–9* (2022), p. 55–58 [ISBN: 978-93-84737-37-5].

20. K.P. Santhosh, C. Nithya. Decay properties of $^{256-339}$Ds superheavy nuclei. *Europ. Phys. J. A* **53**, 189 (2017).
21. K.P.Santhosh, B.Priyanka. predictions on the feasible alpha and cluster decays from $^{298-336}$126 superheavy nuclei. In: *Nuclear Particle Correlations and Cluster Physics* (2017), p. 383–400.
22. Y. Gambhir, A. Bhagwat, M. Gupta. the superheavy elements: Overview. *Indian J. Phys.* **83**, 661 (2009).
23. M. Bhuyan, S. Patra. Magic nuclei in superheavy valley. *Modern Phys. Lett. A* **27**, 1250173 (2012).
24. G.M. Carmel Vigila Bai. *A Systematic Study of Cluster Radioactivity in Transtin Region*. Ph.D. thesis (Manonmanium sundaranar university, 1997).
25. G. Naveya, S. Santhosh Kumar, A. Stephen. A systematic study on α decay chains of superheavy nuclei, $Z = 126$ and 138. *Intern. J. Mod. Phys. E* **29** (6), 2050034 (2020).
26. G. Naveya, S. Santhosh Kumar, S.I.A Philominraj A. Stephen. Study on particle and cluster decay of super heavy nuclei $Z = 130$–144 using Cubic plus Proximity potential with improved transfer matrix method. *Intern. J. Modern Phys. E* **28** (7), 1950051 (2019).
27. C. Qi, F.R. Xu, R.J. Liotta, R. Wyss. Universal decay law in charged-particle emission and exotic cluster radioactivity. *Phys. Rev. Lett.* **103**, 072501 (2009).
28. C. Qi, F.R. Xu, R.J. Liotta, R. Wyss, M.Y. Zhang, C. Asawatangtrakuldee, D. Hu. Microscopic mechanism of charged-particle radioactivity and generalization of the Geiger–Nuttall law. *Phys. Rev. C* **80**, 044326 (2009).
29. V.E. Viola Jr., G.T. Seaborg, J. Inorg. Nuclear systematics of the heavy elements – II. Lifetimes for alpha, beta and spontaneous fission decay. *Nucl. Chem.* **28**, 741 (1966).
30. K.P. Santhosh, C. Nithya. Predictions on the modes of decay of odd Z superheavy isotopes within the range $105 \le Z \le 135$. *Atomic Data and Nuclear Data Tables* **121–122**, 216 (2018).
31. D.N. Poenaru, R.A. Gherghescu, W. Greiner. Single universal curve for cluster radioactivities and α decay. *Phys. Rev. C* **83**, 014601 (2011).
32. D.N. Poenaru, R.A. Gherghescu, W. Greiner. Cluster decay of superheavy nuclei. *Phys. Rev. C* **85**, 034615 (2012).
33. K.P. Santhosh, A. Joseph. Cluster radioactivity in xenon isotopes. *Pramana* **62**, 957 (2004).
34. K.P. Santhosh, C. Nithya. Theoretical studies on the modes of decay of superheavy nuclei. *Phys. Rev. C* **94**, 054621 (2016).
35. Ning Wang, Min Liu, Xizhen Wu, Jie Meng. Surface diffuseness correction in global mass formula. *Phys. Lett. B* **734**, 215 (2014). ar Xiv:1405.2616.

Received 21.06.23

Г.М. Кармел Віджіла Бай, В.С. Аджітра

ПЕРЕДБАЧЕННЯ ЩОДО
АЛЬФА-РОЗПАДУ НАДВАЖКИХ ЯДЕР
ІЗ $Z = 127$–138 НА ОСНОВІ CYE МОДЕЛІ

На основі моделі CYE досліджено альфа-розпад, розпад на кластери і спонтанний поділ важких і надважких ядер. В даній роботі отримано періоди напіврозпаду на кластери для ядер в інтервалі $Z = 127$–138, а також періоди спонтанного поділу цих ядер з використанням наближення двох сфер. Результати порівняно з іншими теоретичними моделями і напівемпіричною формулою Ксу та ін.

Ключові слова: CYE модель, альфа-розпад, надважкі ядра, кластер, спонтанний поділ, період напіврозпаду.