Prediction of decay modes of Z=128 superheavy nuclei within the mass range 301≤A≤338

Usuf Rahaman* and M. Ikram
Department of Physics, Aligarh Muslim University, Aligarh-202002, India.

Introduction

In the 1930s, the first scientific attempt to synthesize superheavy nuclei (SHN) was made by E. Fermi in Rome and O. Hahn, L. Meitner, and F.W. Straβmann in Berlin. They tried to use the neutron capture process to produce transuranium elements [1]. Until now, the synthesis of SHN with Z=110-113 [2, 3] by using cold-fusion reactions and with Z=113-118 [4–6] by ^{48}Ca-induced complete fusion reactions have been made. α-decay and spontaneous fission (SF) are major modes of decay in SHN while some nuclei in the neutron-rich region show β-decay also. The process of α-decay is described by quantum tunneling of an alpha particle through the Coulomb barrier. However, the phenomenon of SF occurs due to large uncertainties involved in masses, charges of the two fragments and energy released during the process. The α-decay and SF half-lives are considered to be the experimental signatures for identification of SHN. In this connection, we tried to predict possible modes of decay of Z=128 within the mass range 301≤A≤338 by analyzing the competition between α-decay, β-decay, and SF.

Formalism

We have employed axially deformed relativistic mean field (RMF) theory using NL3 effective force to calculate binding energies which in turn are used to compute the decay energies. Decay energies Q_α and Q_β, are used as input for estimating the α-decay and β-decay half-lives for the considered isotopic chain of the superheavy nuclei. The α-decay half-lives are calculated using semi-empirical relation by Viola-Seaborg-Sobiczewski (VSS) [7], Royer [9], Brown [8] and Ni *et al.* [10]. Another relation based on generalized liquid drop model (GLDM), proposed by Dasgupta-Schubert and Reyes [11], is also used to calculate α-decay half-lives. The estimation of SF half-life is carried out using the phenomenological formula proposed by Ren *et al.* [12]. The prediction of β-decay half-life is made using the empirical formula put forth by Fiset and Nix [13].

Results and Conclusion

A comparative study of alpha decay, beta decay and spontaneous fission is made for isotopic chain of Z=128 in the mass range 301 to 338 using the semiempirical relations mentioned in the above section. FIG. 1 and TABLE I depict the comparison of the calculated alpha decay, beta decay, and spontaneous fission half-lives against the mass number of the considered chain of isotopes of Z=128 SHN. From the calculations, it is obvious that the α-decay is the principal decay mode in the mass range 301 to 317 and 322 to 332. Alpha decay predicted by the phenomenological formulae are in good agreement with each other and also show a reasonable agreement with the predictions of finite range droplet model (FRDM) [14]. The nuclei with A=318-321 are found to prefer β-decay over other two decay modes. Beyond mass region A≥333, SF becomes the dominant mode of decay due to the heavy mass number of the isotopes. The present calculation suggests that there is a possibility to synthesize the Z=128 superheavy nuclei by observing the α-decay and β-decay.

References

[1] S. Hofmann *et al.*, Eur. Phys. J. A, **52**, 180 (2016).

*Electronic address: urahaman@myamu.ac.in

TABLE I: Decay energies (in MeV) and half-lives of α-decay, β-decay and spontaneous fission for $Z = 128$ isotopic chain and prediction of the mode of decays is given.

Nuclei	Q_α^{RMF}	$\log(T_{1/2}^{\alpha})$ FRDM	$\log(T_{1/2}^{\alpha})$ VSS	Royer	GLDM	Brown	Ni et. al.	$\log(T_{1/2}^{SF})$ Ren-Xu	Q_β^{RMF}	$\log(T_{1/2}^{\beta})$ Fiset-Nix	Mode of decay
$^{301}128$	15.38	–	-8.28	-8.45	-8.330	-8.590	-9.180	> 31	10.699	-0.507	α
$^{302}128$	16.49	–	-9.51	-8.59	-9.380	-8.780	-10.070	> 31	10.408	0.062	α
$^{303}128$	16.53	–	-8.50	-8.64	-8.590	-8.860	-9.370	> 31	10.105	-0.362	α
$^{304}128$	16.56	–	-9.63	-8.69	-9.530	-8.930	-10.170	> 31	9.800	0.214	α
$^{305}128$	16.57	–	-8.56	-8.69	-8.680	-8.950	-9.430	> 31	9.482	-0.201	α
$^{306}128$	16.58	–	-9.65	-8.71	-9.590	-8.990	-10.190	> 31	9.126	0.393	α
$^{307}128$	16.70	–	-8.76	-8.86	-8.910	-9.180	-9.590	> 31	8.772	-0.006	α
$^{308}128$	16.58	–	-9.65	-8.71	-9.630	-9.020	-10.190	> 31	8.541	0.559	α
$^{309}128$	16.10	–	-7.85	-8.09	-8.040	-8.310	-8.820	> 31	8.355	0.116	α
$^{310}128$	15.79	–	-8.41	-7.65	-8.430	-7.830	-9.130	> 31	8.497	0.575	α
$^{311}128$	15.28	–	-6.49	-6.93	-6.730	-7.000	-7.660	> 31	7.790	1.954	α
$^{312}128$	15.02	–	-7.11	-6.55	-7.170	-6.570	-8.020	> 31	7.478	0.891	α
$^{313}128$	14.72	9.29	-5.50	-6.09	-5.780	-6.060	-6.810	> 31	7.155	0.501	α
$^{314}128$	14.58	10.02	-6.33	-5.89	-6.440	-5.830	-7.350	> 31	6.810	1.121	α
$^{315}128$	14.77	8.22	-5.61	-6.18	-5.920	-6.200	-6.900	> 31	6.453	0.755	α
$^{316}128$	14.48	9.22	-6.14	-5.73	-6.290	-5.680	-7.190	> 31	6.138	1.375	α
$^{317}128$	13.49	7.50	-3.13	-4.07	-3.490	-3.770	-4.780	> 31	14.772	-1.291	α
$^{318}128$	7.74	8.15	13.61	11.08	13.320	13.900	9.680	> 31	5.794	1.516	β
$^{319}128$	7.15	> 20	17.61	13.57	17.080	16.790	12.930	> 31	5.472	1.156	β
$^{320}128$	4.63	> 20	35.12	29.37	34.670	35.210	28.050	> 31	5.201	1.777	β
$^{321}128$	4.59	> 20	36.57	29.70	35.890	35.580	29.130	> 31	4.960	1.392	β
$^{322}128$	12.68	> 20	-2.46	-2.59	-2.730	-2.130	-4.050	> 31	4.704	2.017	α
$^{323}128$	12.49	4.36	-0.97	-2.23	-1.440	-1.720	-2.940	> 31	4.412	1.670	α
$^{324}128$	12.42	2.41	-1.86	-2.08	-2.170	-1.570	-3.530	29.806	4.097	2.342	α
$^{325}128$	12.29	0.94	-0.49	-1.83	-1.000	-1.290	-2.530	27.201	3.783	2.030	α
$^{326}128$	12.37	2.01	-1.75	-1.99	-2.100	-1.500	-3.440	24.418	3.482	2.719	α
$^{327}128$	12.41	0.72	-0.76	-2.06	-1.300	-1.590	-2.760	21.456	3.352	2.308	α
$^{328}128$	13.24	1.64	-3.67	-3.63	-4.050	-3.440	-5.090	18.316	4.091	2.352	α
$^{329}128$	12.47	0.66	-0.92	-2.19	-1.490	-1.780	-2.900	14.998	2.853	2.672	α
$^{330}128$	12.19	1.81	-1.32	-1.62	-1.740	-1.130	-3.070	11.502	2.608	3.368	α
$^{331}128$	12.11	1.02	-0.06	-1.46	-0.680	-0.960	-2.170	7.828	2.158	3.278	α
$^{332}128$	11.79	2.27	-0.32	-0.78	-0.790	-0.180	-2.220	3.975	1.953	3.986	α
$^{333}128$	11.56	1.21	1.31	-0.29	0.660	0.370	-0.990	-0.055	1.815	3.639	α/SF
$^{334}128$	12.05	2.06	-0.98	-1.34	-1.480	-0.870	-2.790	-4.264	2.081	3.857	SF
$^{335}128$	12.00	0.33	0.22	-1.23	-0.460	-0.750	-1.930	-8.650	1.896	3.553	SF
$^{336}128$	11.98	1.06	-0.80	-1.18	-1.320	-0.710	-2.630	-13.215	1.725	4.245	SF
$^{337}128$	11.79	0.37	0.73	-0.79	0.020	-0.270	-1.480	-17.957	1.538	3.976	SF
$^{338}128$	11.66	0.04	-0.01	-0.51	-0.580	0.030	-1.960	-22.877	1.336	4.746	SF

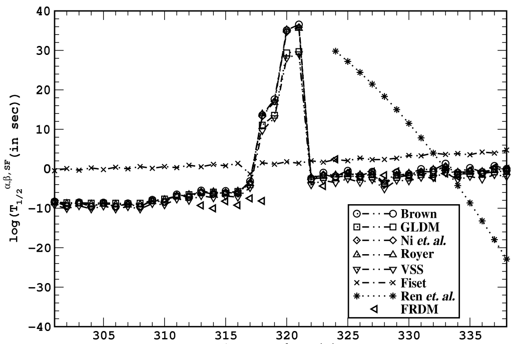

FIG. 1: $\log(T_{1/2})$ for α-decay, β-decay and SF plotted against the mass number for the isotopic chain of Z=128 in the mass range 301 to 338.

[2] S. Hofmann and G. Münzenberg, Rev. Mod. Phys. **72**, 733 (2000).

[3] K. Morita *et al.*, J. Phys. Soc. Jpn. **81**, 103201 (2012).

[4] Y. T. Oganessian *et al.*, Phys. Rev. Lett. **104**, 142502 (2010).

[5] Y. T. Oganessian *et al.*, Phys. Rev. C **74**, 044602 (2006).

[6] Y. Oganessian, J. Phys. G **34**, R165 (2007).

[7] V. E. Viola jr., G.T. Seaborg, J. Inorg. Nucl. Chem. **28**, 741 (1966).

[8] B. A. Brown, Phys. Rev. C **46**, 811 (1992).

[9] G. Royer, J. Phys. G **26**, 1149 (2000).

[10] D. D. Ni, Z. Z. Dong, T. K. *et al.*, Phys. Rev. C **78**, 044310 (2008).

[11] N. Dasgupta-Schubert and M. A. Reyes, At. Data and Nucl.Data Tables **93**, 90 (2007).

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

[13] E. O. Fiset, J. R. Nix, Nucl. Phys. A **193**, 647 (1972).

[14] P. Möller, J. R. Nix, W. D. Wyers, and K.L. Kratz, At. Data Nucl. Data Tables **66**, 131 (1997).