Heavy particle radioactivity of superheavy nuclei $^{306}126$

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Introduction

The definition of heavy-particle radioactivity (HPR) has been modified to include particles released by parents with Z>110 and a daughter around ^{208}Pb that have a Z_e>28. In comparison to heavier SHs, calculations for superheavy (SH) nuclei with Z=104–124 reveals a tendency toward shorter half-lives and a higher branching ratio [1]. The competition between HPR and α decay have been investigated in the region of superheavy region Z = 104–124 [2]. Using modified generalized liquid drop model, earlier researchers investigated HPR in superheavy element Z=126 [3]. The role of deformations and shell corrections were studied in prediction of HPR [4]. Many theoretical investigations shows prediction of cluster and alpha decay process in the superheavy nuclei [5-7].

Hence, we have motivated to study HPR in the superheavy nuclei ^{306}126. We have also made an attempt to study HPR such as ^{58}Ni to ^{126}I using Coulomb and proximity potential model (CPPM). The role of deformations are included in the evaluation of potentials. The decay chain of superheavy nuclei ^{299}119 is also investigated.

Theoretical Frame work

The HPR half-lives are evaluated using CPPM by including deformation effects. The total potential is the sum of Coulomb V_C and Proximity potential V_P and it is expressed as;

$$V = V_C + V_P \qquad (1)$$

The Coulomb interaction potential is given by,

$$V_c = \frac{Z_1 Z_2 e^2}{r}\left[1 + \frac{3R^2}{5r^2}\beta_2 Y_{20}(\theta) + \frac{3R^4}{9r^4}\beta_4 Y_{40}\right] \qquad (2)$$

here Z_1 and Z_2 are the atomic numbers of daughter and HPR nuclei respectively. The term ‘r’, R, β and $Y_{20}(\theta)$ are the separation distance, radius of the nuclei, quadrupole deformation parameter and spherical hormanic function respectively. Proximity potential is evaluated as follows;

$$V_P = 4\pi\gamma b\left[\frac{C_1 C_2}{C_1 + C_2}\right]\phi \qquad (3)$$

The penetration probability is evaluated using wkb approximation. The half-lives are evaluated as explained in detail in literature [3].

Results and Discussions

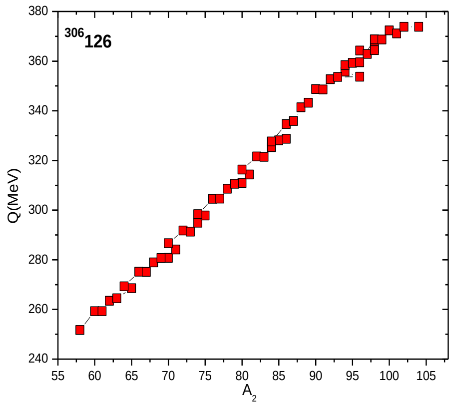

Fig 1: Variation of Q-values during HPR with mass number of heavy particle emitted from the parent nuclei ^{306}126.

The HPR (^{58}Ni to ^{126}I) half-lives are studied in the superheavy nuclei ^{306}120 using CPPM. The Q-value of the reaction is evaluated using mass excess values available in literature [8,9]. The possibility of heavy particle emissions were considered using the condition that $Z_e^{\min} = 28$ and $Z_e^{\max} = Z - 82$. The figure 1 shows a plot of amount of energy released during HPR with mass number of heavy particle emitted in case of superheavy nuclei ^{306}126. This graph shows that the Q-values increase along with the mass number of heavy particles. This demonstrates how the heavy particle emission directly affects the Q-values.

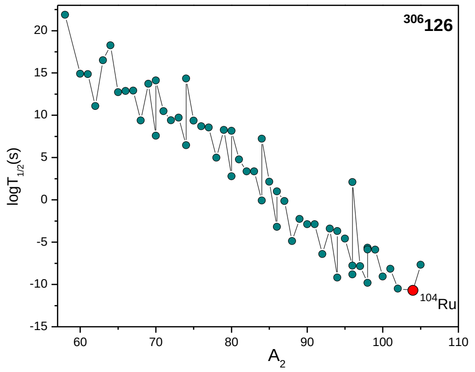

Fig 2: A variation of $logT_{1/2}$ of HPR (^{58}Ni to ^{126}I) from the parent nuclei ^{306}126 with that of mass number of heavy particle emission.

The half-lives evaluated during HPR are plotted as a function of mass number of A_2 and it is shown in figure 2. From this figure it is observed that the nuclei ^{104}Ru shows shorter half-lives when compared to their neighboring ones. This might be owing to shell closure effects caused by both daughter and heavy particle emission, i.e. ^{202}Pb+^{104}Ru nuclei. Further, we have investigated decay chain of superheavy nuclei ^{306}126. The different decay modes such as alpha-decay [10], beta-decay and spontaneous fission [11] were investigated and identified decay chain for the superheavy nuclei ^{306}126.

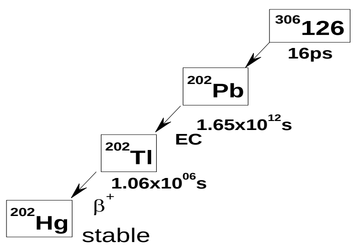

Fig 3: Decay chain of superheavy nuclei ^{306}126.

The figure 3 shows decay chain of superheavy nuclei ^{306}126. The nuclei ^{306}126 undergoes ^{104}Ru HPR and it converts to ^{202}Pb within 16ps. Again ^{202}Pb becomes unstable against electron capture and with the half-life of 1.65×10^{12}s the nuclei convert to ^{202}Tl. Further, ^{202}Tl cannot survive β^+-decay, within a half-life of 1.06×10^{06}s it becomes stable nuclei with ^{202}Hg. Hence, if ^{306}126 undergoes HPR, then finally it attains stable nuclei with ^{202}Hg.

Conclusions:

The HPR of superheavy element ^{306}126 is studied using CPPM. The logarithmic half-lives of HPR shows shorter values for the combination of ^{202}Pb+^{104}Ru. Hence, it is clear that the combination of ^{202}Pb+^{104}Ru posses shorter half-lives due to shell closure effects. Hence, the most possible HPR from the superheavy nuclei ^{306}126 consists of fragment configuration ^{202}Pb and ^{104}Ru. Further, decay chain of superheavy nuclei ^{306}126 is also investigated. The nuclei ^{306}126 if it undergoes HPR, then finally it attains stable nuclei with ^{202}Hg. This study finds an important role in future experiments on HPR.

References

[1] D. N. Poenaru, R. A. Gherghescu, and W. Greiner, Phys. Rev. Lett. 107, 062503, (2011).
[2] D. N. Poenaru et al., J. Phys.: Conf. Ser. 436, 012056(2013).
[3] A.M.Nagaraja et al., Nucl. Phys, A 1015, 122306(2021).
[4] Gudveen Sawhney et al., Eur. Phys. J. A 50, 175 (2014).
[5] A. M. Nagaraja, et al., Braz. J. Phys. 52:97 (2022).
[6] A.M.Ngaraja et al., Pramana -J. Phys. 95:194 (2021).
[7] A. M. Nagaraja, et al., Eur. Phys. J. Plus 135:814 (2020).
[8] https://www-nds.iaea.org/RIPL-3/
[9] H.C. Manjunatha et al., Indian J Phys. 96, 1237–1246 (2022).
[10] H.C.Manjunatha, N.Sowmya, Nucl. Phys. A 969 (2018) 68–82.
[11] M.G.Srinivas et al., Nucl. Phys. A 995: 1216 (2020).

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