α-decay half-lives and α-cluster preformation factors of nuclei around N = Z line

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Abstract

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Full Text

α-Decay Half-Lives and α-Cluster Preformation Factors of Nuclei Around the N = Z Line

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Abstract

In this work, we employ a microscopic effective nucleon-nucleon interaction derived from the Dirac-Brueckner-Hartree-Fock G matrix, starting from a bare nucleon-nucleon interaction, to investigate the α-decay half-lives of nuclei near the N = Z line. Specifically, the α-nucleus potential is constructed by doubly folding the effective nucleon-nucleon interaction with the density distributions

of both the α-cluster and the daughter nucleus. Additionally, the α-cluster preformation factor is extracted using a cluster formation model.

Our calculations demonstrate that the computed half-lives reproduce experimental data well. We then predict α-decay half-lives for nuclei around N = Z where experimental data are unavailable, which will be helpful for identifying new α-decay candidates in future experiments. Furthermore, by analyzing the proton-neutron correlation energy and the two-proton-two-neutron correlation energy for Z = 52 and Z = 54 isotopes, we explain the evolution of the α-cluster preformation factor with neutron number N. We find that the two-proton-two-neutron interaction plays a more important role in α-cluster preformation than the proton-neutron interaction, while the proton-neutron interaction gives rise to the odd-even effect in the α-cluster preformation factor.

Keywords: α-decay; nuclei around N = Z line; Dirac-Brueckner-Hartree-Fock approach; Cluster formation model
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Introduction

α-decay has long been recognized as a powerful tool for probing the structure and properties of unstable nuclei. Experimental observations show that α-radioactivity occurs predominantly in heavy nuclei [1]. In recent years, the mass region dominated by α-decay has been continuously expanded through rapid advances in experimental techniques, leading to the successful synthesis of numerous superheavy α emitters via cold-, warm-, and hot-fusion reactions [2–4]. In addition, α-radioactivity has been detected in several medium-mass nuclei approaching the N = Z line, including $^{105-110}$Te [5–9], $^{108-113}$I [10, 11], $^{109-112}$Xe [5, 6, 12, 13], ^{112},^{114}Cs [13, 14], and ^{114}Ba [15].

Recently, the Argonne National Laboratory experimentally observed a new α-decay chain ^{108}Xe $\rightarrow$ ^{104}Te $\rightarrow$ ^{100}Sn, including measurements of the α-particle kinetic energy and α-decay half-lives for the new α emitters ^{108}Xe [Eα = 4.4(2) MeV, $T_1/_2 = 58^{+106}_{23}$ µs] and ^{104}Te [Qα = 4.9(2) MeV, $T_1/_2 < 18$ ns] produced via the fusion-evaporation reaction ^{54}Fe(^{58}Ni, 4n)^{108}Xe [16]. This represents not only the first observation of α-radioactivity leading to a heavy self-conjugate nucleus ^{100}Sn but also provides valuable insights into the physical mechanism of α-clustering near the N = Z line. Consequently, studies of α-decay properties around the N = Z line have attracted increasing attention [17–27], as these α emitters are crucial for understanding nuclear structure and properties approaching the N = Z line as well as shell effects around N = Z = 50 [17–27].

α-decay was first described as a quantum tunneling phenomenon by Gamow [28] and independently by Condon and Gurney [29] in 1928. Building upon this picture, various macroscopic and microscopic approaches have been developed [30–49]. Among these, the α-cluster potential in the nuclear surface region plays a critical role in determining the half-life. Typically, the α-cluster potential

is constructed by double-folding the density distributions of the α-particle and daughter nucleus with an effective nucleon-nucleon (n-n) interaction. Numerous versions of effective n-n interactions exist, based on different physical origins such as the Skyrme interaction [43–45, 50], the Michigan-3-Yukawa interaction [46, 47, 51], and meson-exchange n-n interactions [48, 49, 52].

However, uncertainties remain in our current understanding of the n-n interaction, leading to discrepancies in computational accuracy when calculating α-decay half-lives using different versions of effective n-n interactions [43–49]. Therefore, employing a reasonable effective n-n interaction is crucial for reproducing experimental α-decay half-lives, while conversely, α-decay experimental data provide an excellent testing ground for effective n-n interactions.

In Ref. [53], an effective microscopic n-n interaction was derived through effective meson exchange within the Dirac-Brueckner-Hartree-Fock (DBHF) G matrix, starting from a bare n-n interaction. This interaction has been successfully applied to investigate nuclear structure and scattering [54–57]. Subsequently, the DBHF effective n-n interaction was used to estimate α-decay half-lives of superheavy nuclei, yielding good agreement with experimental data [58]. Given the recent discovery of numerous α emitters approaching the N = Z line, it is of interest to extend the DBHF approach to this mass region to further test the effective n-n interaction. Moreover, previous studies have indicated enhanced α-particle formation probabilities around N = Z nuclei due to strong overlap between neutron and proton Fermi energies [17–27], though the evolution of the α-cluster preformation probability with N remains incompletely understood. The cluster formation model (CFM) has recently been employed to extract α-cluster preformation probabilities [17, 59, 60]. Therefore, in this work we utilize both the DBHF approach and CFM to study α-decay properties of nuclei around the N = Z line and the evolution of the α-cluster preformation probability with N.

This article is organized as follows: Section II presents the theoretical frameworks of DBHF and CFM, Section III provides numerical results and discussions, and Section IV concludes.

II. Theoretical Framework

The total interaction potential V(R) between the α-cluster and daughter nucleus is given by

$$V(R) = V_N(R) + V_C(R) + V_l(R).$$

Here V(R) comprises the nuclear potential V_N(R), Coulomb potential V_C(R), and centrifugal potential V_l(R), respectively, where R is the distance between the mass centers of the α-cluster and daughter nucleus.

The nuclear potential V_N(R) is obtained by doubly folding the effective n-n

interaction with the nucleon density distributions of both the α-particle and daughter nucleus [58]:

$$V_N(R) = \lambda \int\int \rho_\alpha(\mathbf{r}_1)\rho_d(\mathbf{r}_2)V_{\rm ILDA}(\varepsilon,\rho,s)d\mathbf{r}_1 d\mathbf{r}_2,$$

where V_{ILDA} is the effective n-n interaction incorporating the improved local density approximation (ILDA) derived from the DBHF G matrix starting from a bare n-n interaction [53, 57, 58], expressed as

$$V_{\rm ILDA}(\varepsilon,\rho,s) = g(s)V_{\rm eff},$$

$$g(s) = \left(\frac{t_R}{\pi}\right)^{-3} \exp\left(-\frac{s^2}{t_R^2}\right),$$

with s = R + r_2 - r_1 representing the relative vector between interacting nucleon pairs (r_1 and r_2 being the coordinates of nucleons in the center-of-mass frames of the α-particle and daughter nucleus, respectively), and t_R is a range parameter.

In Eq. (2), λ, , and denote the renormalization factor, local nuclear matter density, and kinetic energy in the nucleon-nucleon center-of-mass frame, respectively. For V_{eff}, it represents the effective n-n interaction without ILDA and is calculated via the Thomas-Fermi approximation: V_{eff} = U_{eff}/ , where U_{eff} is the nucleon self-energy in the nuclear medium.

In the DBHF approach, the real part of the nucleon self-energies is parametrized through polynomial expansions:

$$\mathrm{Re}\, U_{\rm eff}(\rho,E) = \sum_{i,j} a_{ij}\rho^i\varepsilon^{j-1},$$

where E refers to the total nucleon energy in the nuclear medium (E = + M), with M being the nucleon rest mass. The coefficients a_{ij} are listed in Table I [57, 58].

TABLE I: Values of the coefficients a_{ij} in Eq. (5).

i	j=1	j=2	j=3
1	-0.797×10^3	0.222×10^1	-0.825×10^{-3}
2	0.366×10^4	-0.438×10^1	-0.696×10^{-2}
3	-0.515×10^4	0.584×10^1	0.221×10^{-1}

In Eq. (2), the local density is calculated using the geometric average of the density distributions of the two interacting nuclei [57, 58, 61]:

$$\rho = \sqrt{\rho_\alpha(\mathbf{r}_1)\rho_\alpha(\mathbf{r}_2)}.$$

The nucleon density distribution of the α-particle _α(r) is given by a Gaussian form [62]:

$$\rho_\alpha(r) = \frac{4}{b_\alpha^3 \pi^{3/2}} \exp\left(-\frac{r^2}{b_\alpha^2}\right),$$

where b_α = 1.1932 fm.

The nucleon density distribution of the daughter nucleus _d(r) is described by a spherically symmetric Fermi function [57, 58]:

$$\rho_d(r) = \frac{\rho_0}{1 + \exp[(r-c)/a]},$$

with central density $_0 = 3/(4\pi c^3(1 + \pi^2 a^2/c^2))$, half-density radius c = $1.07A^1/^3$, and diffuseness a = 0.54 fm.

The renormalization factor λ is determined by the Bohr-Sommerfeld quantization condition:

$$\int_{R_1}^{R_2} \sqrt{\frac{2\mu}{\hbar^2}|Q_\alpha - V(r)|}\, dr = (2n+1) = (G - L + 1),$$

where n is the node number of the radial wave function, and the global quantum number G = 16 (for $50 < Z, N \leq 82$) [58, 63] is adopted. $R_1 = 0$ represents the first turning point, while the second turning point R_2 and third turning point R_3 are determined by solving V(R) = Q_α.

The Coulomb potential V_C(R) in Eq. (1) is given by

$$V_C(R) = \begin{cases} \frac{Z_\alpha Z_d e^2}{R} & \text{for } R > R_C, \\ \frac{Z_\alpha Z_d e^2}{2R_C}\left(3 - \frac{R^2}{R_C^2}\right) & \text{for } R \leq R_C, \end{cases}$$

where Z_α and Z_d denote the proton numbers of the α-particle and daughter nucleus, respectively, and R_C = $1.2A^1/^3$ is the Coulomb radius of the daughter nucleus (A_d being the daughter nucleus mass number).

The centrifugal potential V_l(R) in Eq. (1) is calculated as

$$V_l(R) = \frac{l(l+1)\hbar^2}{2\mu R^2},$$

where l is the angular momentum carried by the α-cluster and is the reduced mass: = M_αM_d/M_p, with M_α, M_d, and M_p being the masses of the α-particle, daughter nucleus, and parent nucleus, respectively.

The α-decay half-life is calculated via

$$T_{1/2} = \frac{\hbar \ln 2}{\Gamma_\alpha},$$

where Γ_α is the α-decay width, expressed as

$$\Gamma_\alpha = P_\alpha F \exp\left(-2\int_{R_2}^{R_3} k(R)\, dR\right).$$

In Eq. (13), F is the normalization factor:

$$F = \exp\left(\int_{R_1}^{R_2} 2k(R)\, dR\right),$$

with wave number k(R) given by

$$k(R) = \sqrt{\frac{2\mu}{\hbar^2}|Q_\alpha - V(R)|},$$

where Q_α is the α-decay energy.

Within the CFM approach, the preformation factor P_α of an α-cluster in a nucleus is [17, 59, 60]:

$$P_\alpha = \frac{E_{f\alpha}}{E_{\text{tot}}} = \frac{E_{f\alpha}}{E_{f\alpha} + E_r},$$

where E_{fα} is the α-cluster formation energy associated with interactions among the four nucleons in the α-cluster, E_r is the energy for relative motion derived from the α-particle orbiting the daughter nucleus in the parent nucleus ground state, and E_{tot} = E_{fα} + E_r is the total energy for the α-clustering state [17, 59, 60]. Typically, calculating P_α requires solving the corresponding Schrödinger equation for E_{fα} and E_{tot}. However, by analyzing surface nucleon-nucleon interactions, these values can be approximately obtained from experimental separation energies [17, 59, 60]:

$$E_{f\alpha} = \begin{cases} 2S_p + 2S_n - S_\alpha & \text{(even-even)} \\ 2S_p + S_{2n} - S_\alpha & \text{(even-odd)} \\ S_{2p} + 2S_n - S_\alpha & \text{(odd-even)} \\ S_{2p} + S_{2n} - S_\alpha & \text{(odd-odd)} \end{cases}$$

$$E_{\text{tot}} = S_\alpha(A, Z),$$

where S_p, S_n, S_{2p}, S_{2n}, and S_α represent one-proton, one-neutron, two-proton, two-neutron, and α-cluster separation energies, respectively. These are obtained from:

$$\begin{aligned} S_p(A, Z) &= B(A, Z) - B(A-1, Z-1), \\ S_n(A, Z) &= B(A, Z) - B(A-1, Z), \\ S_{2p}(A, Z) &= B(A, Z) - B(A-2, Z-2), \\ S_{2n}(A, Z) &= B(A, Z) - B(A-2, Z), \\ S_\alpha(A, Z) &= B(A, Z) - B(A-4, Z-2), \end{aligned}$$

where B(A, Z) is the binding energy of a nucleus with mass number A and proton number Z. Experimental B(A, Z) values are generally taken from the AME2020 atomic mass table [64]; for nuclei lacking experimental data, values are taken from the Weizsäcker-Skyrme-4 (WS4) mass table [65].

III. Results and Discussions

First, the parameter t_R in Eq. (4) must be determined through ^{2} least-square fitting:

$$\chi^2 = \sum_i \left(\frac{T^{\text{expt}}_{1/2,i} - T^{\text{cal}}_{1/2,i}}{T^{\text{expt}}_{1/2,i}} \right)^2,$$

where T_{1/2,i}^{expt} and T_{1/2,i}^{cal} are the experimental and calculated α-decay half-lives using experimental Q_α values, respectively. Through Eq. (24), we find that ^{2} reaches a minimum at t_R = 0.9 fm, which is the optimal value in our DBHF model framework.

Using ^{112}Xe as an example, we obtain the total interaction potential V(R), nuclear potential V_N(R), and Coulomb potential V_C(R) as functions of R, shown in Fig. 1 [Figure 1: see original paper]. The figure reveals that the well depth of V(R) is approximately -115 MeV. Solving V(R) = Q_α^{expt} = 3.33 MeV yields the second and third turning points R_2 = 6.97 fm and R_3

= 44.93 fm, respectively. The second turning point R_2 located within the nuclear surface region indicates that the α-particle is preformed inside the nucleus before tunneling through the barrier. In our half-life calculation, we apply the Bohr-Sommerfeld quantization condition from Eq. (9), determining the renormalization factor $\lambda = 0.60$. The resulting calculated α-decay half-life is 4.27×10^2 s, in good agreement with the experimental value T_{1/2}^{expt} = 2.25×10^2 s.

FIG. 1: (Color online) Total interaction potential V(R) (red solid curve), nuclear potential V_N(R) (green dot-dash curve), and Coulomb potential V_C(R) (blue dash curve) for ^{112}Xe.

Encouraged by this agreement, we extend our model to calculate α-decay half-lives for additional nuclei near N = Z, including Te, I, Xe, Cs, and Ba isotopes, as listed in Table II. The first column indicates transitions between initial and final α-emitter states, while the second and third columns show the spin-parity of parent and daughter nuclei. The fourth column gives the minimal orbital angular momentum (l_{min}) carried by the α-particle, determined by spin-parity selection rules ($l_{min} = 0$ when J^π values are unknown). Experimental Q_α values [64] appear in the fifth column, preformation factors P_α in column 6, and experimental and calculated α-decay half-lives in columns 7 and 8. The final column lists logarithmic hindrance factors $\log_{10}HF = \log_{10}(T_{1/2}^{expt}) - \log_{10}(T_{1/2}^{cal})$.

To more clearly illustrate the agreement between calculated and experimental half-lives, $\log_{10}HF$ values are plotted in Fig. 2 [Figure 2: see original paper], along with results from the generalized liquid drop model (GLDM) [20]. Generally, $\log_{10}HF$ values within $\pm$1.0 indicate satisfactory agreement [35, 36]. Figure 2 shows that more DBHF model results fall within this range, suggesting better agreement with experimental data. This success validates the effective n-n interaction obtained from the G matrix based on a bare n-n interaction. To quantitatively compare model accuracies, we calculate the standard deviation $\bar{\sigma}^2$ between calculated and experimental half-lives:

$$\bar{\sigma}^2 = \sqrt{\frac{1}{N}\sum_i \left(\log_{10} T^{\rm expt}_{1/2,i} - \log_{10} T^{\rm cal}_{1/2,i}\right)^2}.$$

The resulting $\bar{\sigma}^2$ values are 0.62 for DBHF and 0.78 for GLDM, further confirming DBHF' s superior accuracy. Additionally, we observe enhanced nuclear stability with increasing N in each isotopic chain, attributed to increasing symmetry energy [18].

Motivated by DBHF' s success, we predict α-decay half-lives for N Z nuclei lacking experimental data, presented in Table III. These predictions will aid in identifying new nuclides or isotopes in future experiments.

Our calculations incorporate P_α values extracted via CFM. Tables I and II

show that most nuclei have P_α values of order 10^{-2}, larger than those near ^{208}Pb, consistent with previous work [17, 18, 24, 25]. Our earlier studies [18, 19] emphasized that α-cluster preformation depends not only on the mean field including pairing interactions but also crucially on higher-order nucleon correlations, particularly proton-neutron correlations [21, 25, 59, 67, 68].

Figure 3(a) [Figure 3: see original paper] shows P_α values for Z = 52 and Z = 54 isotopes versus N. The P_α values increase as nuclei approach the N = Z line, indicating enhancement by proton-neutron correlations in similar single-particle states—one reason for superallowed α-decay near the doubly magic nucleus ^{100}Sn. Odd-A nuclei exhibit smaller P_α values than neighboring even-even nuclei, known as the odd-even effect. To understand P_α evolution with N, we calculate proton-neutron correlation energy E_{p-n} and two-proton-two-neutron correlation energy E_{2p-2n} [21, 25, 59]:

$$E_{p-n} = B(A,Z) + B(A-2,Z-1) - B(A-1,Z-1) - B(A-1,Z),$$
$$E_{2p-2n} = B(A,Z) + B(A-4,Z-2) - B(A-2,Z-2) - B(A-2,Z).$$

Here B(Z, N) values are taken from AME2020 [64] or WS4 [65] mass tables. Figure 3(b) [Figure 3: see original paper] plots E_{p-n} and E_{2p-2n} for Z = 52 and Z = 54 isotopes. The E_{2p-2n} values increase as N decreases, mirroring the P_α evolution in Fig. 3(a), and are substantially larger than E_{p-n} values. This suggests that two-proton-two-neutron interactions are more essential than proton-neutron interactions for α-particle preformation, consistent with recent findings [25]. Furthermore, E_{p-n} exhibits odd-even staggering with N, which produces the odd-even effect in P_α shown in Fig. 3(a).

FIG. 2: (Color online) Logarithmic hindrance factors $\log_{10}$HF for nuclei around N = Z. Red squares and blue triangles represent DBHF and GLDM [20] results, respectively.

FIG. 3: (Color online) (a) P_α values for Z = 52 and Z = 54 isotopes versus N. (b) Same as (a), but for proton-neutron correlation energy E_{p-n} and two-proton-two-neutron correlation energy E_{2p-2n}.

IV. Conclusion

In this work, we investigate α-decay half-lives of nuclei near the N = Z line using a microscopic effective n-n interaction obtained within the DBHF G matrix from a bare n-n interaction. The α-cluster preformation factor P_α extracted via CFM is incorporated in our half-life calculations. We find that calculated α-decay half-lives agree well with experimental data, with higher accuracy than GLDM, demonstrating the success and validity of both the effective n-n interaction and CFM. We predict α-decay half-lives for nuclei around N = Z lacking experimental data, which will be valuable for identifying new nuclides in future experiments. By analyzing proton-neutron correlation energy E_{p-n} and

two-proton-two-neutron correlation energy E_{2p-2n}, we find that two-proton-two-neutron interactions are more crucial than proton-neutron interactions for α-cluster preformation, while the odd-even staggering of E_{p-n} leads to the odd-even staggering of P_α.

Finally, we note that cluster radioactivity [43, 69–71], proton radioactivity [72–75], and two-proton radioactivity [76–80] represent important decay modes for unstable nuclei. Extending the DBHF effective n-n interaction to study these radioactivities is work in progress.

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TABLE II: Comparison of experimental and calculated α-decay half-lives for nuclei approaching N = Z (in seconds). Spin-parity J^π, experimental α-decay energies (in MeV), and experimental half-lives are taken from Refs. [64, 66].

Emitter	J^π (parent)	J^π (daughter)	l_{min}	Q_α^{expt} (MeV)	P_α	$T_{1/2}^{expt}$ (s)	$T_{1/2}^{cal}$ (s)	$\log_{10}$HF
Z = 52								
^{104}Te → ^{100}Sn + α	0+	0+	0	4.900*	0.305*	$< 4 \times 10^{-9}$	5.84×10^{-8}	< -1.16
^{105}Te → ^{101}Sn + α	7/2+	5/2+	2	4.100*	0.173*	6.33×10^{-7}	1.22×10^{-7}	0.71

Emitter	J^π (parent)	J^π (daughter)	l_{min}	Q_α^{expt} (MeV)	P_α	$T_{1/2}^{expt}$ (s)	$T_{1/2}^{cal}$ (s)	$\log_{10}$HF
^{106}Te → ^{102}Sn + α	0+	0+	0	3.990	0.332	7.8×10^{-5}	1.12×10^{-4}	-0.16
^{107}Te → ^{103}Sn + α	5/2+	5/2+	0	3.530	0.190	4.6×10^{-3}	5.45×10^{-3}	-0.07
^{108}Te → ^{104}Sn + α	0+	0+	0	3.330	0.226	4.286×10^{0}	5.42×10^{0}	-0.10
^{109}Te → ^{105}Sn + α	5/2+	5/2+	0	2.880	0.183	1.128×10^{2}	3.42×10^{-2}	0.52
Z = 53								
^{108}I → ^{104}Sb + α			0	3.800*	0.239	2.653×10^{-2}	8.78×10^{-3}	0.48
^{109}I → ^{105}Sb + α	1/2+, 3/2+	5/2+	2	3.400*	0.119	6.629×10^{-1}	1.58×10^{0}	-0.38
^{110}I → ^{106}Sb + α			0	3.200*	0.226	3.906×10^{0}	2.05×10^{2}	-1.72
^{111}I → ^{107}Sb + α	5/2+	5/2+	0	2.900	0.096	2.841×10^{3}	4.41×10^{2}	0.81
^{113}I → ^{109}Sb + α			0	2.500*	0.223	1.994×10^{7}	1.83×10^{7}	0.04
Z = 54								

Emitter	J^π (parent)	J^π (daughter)	l_{min}	Q_α^{expt} (MeV)	P_α	$T_{1/2}^{expt}$ (s)	$T_{1/2}^{cal}$ (s)	$\log_{10}$HF
^{108}Xe → ^{104}Te + α	0+	0+	0	4.400*	0.138	5.8 × 10^{-5}*	4.30 × 10^{-8}	3.13
^{109}Xe → ^{105}Te + α	7/2+	5/2+	2	3.700*	0.207	1.3 × 10^{-2}	2.68 × 10^{-6}	3.69
^{110}Xe → ^{106}Te + α	0+	0+	0	3.530	0.226	1.453 × 10^{-1}	1.97 × 10^{-1}	-0.13
^{111}Xe → ^{107}Te + α	5/2+	5/2+	0	3.330	0.096	7.115 × 10^{0}	3.87 × 10^{0}	0.26
^{112}Xe → ^{108}Te + α	0+	0+	0	3.330	0.268	2.25 × 10^{2}	4.27 × 10^{2}	-0.28
Z = 55								
^{112}Cs → ^{108}I + α			0	3.200*	0.086*	> 1.885 × 10^{-1}	1.12 × 10^{0}	> -0.77
^{114}Cs → ^{110}I + α			0	2.900	0.132	3.167 × 10^{3}	5.29 × 10^{3}	-0.22
Z = 56								
^{114}Ba → ^{110}Xe + α	0+	0+	0	3.200	0.256	5.111 × 10^{1}	1.52 × 10^{2}	-0.47

*Values calculated using the WS4 mass model table [65].

TABLE III: Predicted α-decay half-lives for nuclei approaching N = Z (in seconds). Spin-parity J^π and Q_α values (in MeV) are taken from Refs. [64, 66].

Emitters	J^π (parent)	l_{min}	Q_α (MeV)	P_α	T_{1/2}^{cal} (s)
Z = 52					
^{110}Te → ^{106}Sn + α	0+	0	3.100	0.239	2.31×10^{6}
^{111}Te → ^{107}Sn + α	5/2+	2	2.700	0.119	4.04×10^{8}
^{112}Te → ^{108}Sn + α	0+	0	2.900	0.226	2.67×10^{13}
^{113}Te → ^{109}Sn + α	7/2+	2	2.500	0.096	3.36×10^{18}
^{114}Te → ^{110}Sn + α	0+	0	2.700	0.223	1.15×10^{23}
Z = 53					
^{106}I → ^{102}Sb + α		0	4.200*	0.138*	4.30×10^{-8}
^{107}I → ^{103}Sb + α	5/2+	2	3.800*	0.207	2.68×10^{-6}
^{114}I → ^{110}Sb + α		0	2.800	0.055	2.65×10^{12}
^{115}I → ^{111}Sb + α	5/2+	0	2.500	0.146	4.18×10^{14}
Z = 54					
^{113}Xe → ^{109}Te + α	5/2+	2	3.100*	0.137	5.40×10^{4}
^{114}Xe → ^{110}Te + α	0+	0	3.000	0.268	4.43×10^{7}
^{115}Xe → ^{111}Te + α	5/2+	2	2.700	0.132	1.30×10^{10}
^{116}Xe → ^{112}Te + α	0+	0	2.800	0.256	8.72×10^{14}
Z = 55					
^{111}Cs → ^{107}I + α	3/2+	2	3.400*	0.183*	1.65×10^{0}
^{113}Cs → ^{109}I + α	3/2+	2	3.000	0.134	3.60×10^{2}
^{115}Cs → ^{111}I + α	1/2+, 3/2+	0	2.600	0.149	1.12×10^{9}
^{116}Cs → ^{112}I + α	9/2+	0	2.400	0.068	1.62×10^{10}
^{117}Cs → ^{113}I + α	9/2+	0	2.200	0.143	1.24×10^{16}
Z = 56					
^{113}Ba → ^{109}Xe + α	5/2+	2	3.200*	0.195*	1.24×10^{1}

Emitters	J^π (parent)	l_{min}	Q_α (MeV)	P_α	T_{1/2}^{cal} (s)
^{115}Ba → ^{111}Xe + α	5/2+	2	2.800	0.133	2.74×10^{5}
^{116}Ba → ^{112}Xe + α	0+	0	2.900	0.231	7.56×10^{4}
^{117}Ba → ^{113}Xe + α	3/2+	0	2.500	0.160	2.45×10^{15}
^{118}Ba → ^{114}Xe + α	0+	0	2.600	0.221	1.24×10^{12}

*Values calculated using the WS4 mass model table [65].

Note: Figure translations are in progress. See original paper for figures.