α decay properties of ^{297}Og within the two-potential approach*

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Abstract: The α decay half-life of the unknown nucleus ^{297}Og is predicted within the two-potential approach, and α preformation probabilities of 64 odd-A nuclei in the region of proton numbers $82<Z<126$ and neutron numbers $152<N<184$, from ^{251}Cf to ^{295}Og, are extracted. In addition, based on the latest experimental data, a new set of parameters for α preformation probabilities considering the shell effect and proton-neutron interaction are obtained. The predicted α decay half-life of ^{297}Og is 0.16 ms within a factor of 4.97. The predicted spin and parity of the ground states for ^{269}Sg, ^{285}Fl and ^{293}Lv are $3/2^+$, $3/2^+$ and $5/2^+$, respectively.

Keywords: α decay, ^{297}Og, α preformation probability, two-potential approach

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1 Introduction

For several decades, the synthesis of superheavy nuclei has been a hot area of research in nuclear physics. Experimentally, elements 107–112 have been synthesized in cold-fusion reactions at the separator for heavy-ion products (SHIP) facility at the GSI Helmholtz Centre for Heavy Ion Research in Germany [1–3]. Through hot-fusion reactions between ^{48}Ca beams and radioactive actinide targets, elements 113–118 have been synthesized [4–9]. In the future, the synthesis of ^{297}Og is expected to happen via the reaction $^{249}\mathrm{Cf}+^{48}\mathrm{Ca}\rightarrow^{297}\mathrm{Og}$ at the Flerov Laboratory of Nuclear Reactions (FLNR) in Dubna, Russia [3]. If the experiment succeeds, ^{297}Og will be the nucleus with the largest number of neutrons observed, 179, and the closest to predicted neutron number N=184 shell closure [10, 11].

Spontaneous fission and α decay are the two main decay modes of superheavy nuclei. For superheavy nuclei around Rf, spontaneous fission is a stronger candidate than α decay [12]. For the majority of recently synthesized proton-rich superheavy nuclei, α decay is the dominant decay mode because shell closure makes the superheavy nuclei stable against spontaneous fission [12]. Recently, Bao et al. also predicted that the decay mode of ^{297}Og is α decay [13]. α decay, as an important tool to study superheavy nuclei, provides abundant information about the nuclear structure and stability of superheavy nuclei. There are many theoretical models used to study α decay, including the fission-like model, shell model, cluster model, and so on [14–23]. The two-potential approach (TPA) [24, 25] was initially put forward to investigate quasi-stationary problems. Recently, it has been widely used to deal with α decay [26–33]. In our previous works [29–33], we adopted the TPA to systematically study α decay half-lives of even-even, odd-A and doubly-odd nuclei, and the calculations could reproduce the experimental data well.

The aim of this work is to predict the α decay half-life $T_{1/2}$ of ^{297}Og. Because $T_{1/2}$ is sensitive to α decay energy Q_α, how to select a precise Q_α is one of the key questions in predicting $T_{1/2}$ for ^{297}Og. Theoretical predictions of Q_α for superheavy nuclei are performed using the following mass models: Möller et al. (FRDM) [34], Duflo and Zuker (DZ) [35], Nayak and Satpathy (INM) [36], Wang and Liu (WS3+) [37], Wang et al. (WS4+) [38, 39], Muntian et al. (HN) [40, 41], Kuzmina et al. (TCSM) [42], Goriely et al. (HFB31) [43], and Liran et al. (SE) [44]. It is found that the WS3+ model [37] is the most accurate in reproducing the experimental Q_α

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of superheavy nuclei [45, 46]. To accurately predict the half-life of ^{297}Og, we systematically investigate α preformation probabilities of 64 odd-A nuclei with $82<Z<126$ and $152<N<184$, from ^{251}Cf to ^{295}Og, within TPA. The α decay energy and half-lives are taken from the latest evaluated nuclear properties table NUBASE2016 [47] and evaluated atomic mass table AME2016 [48, 49], except for Q_α of ^{297}Og, which is taken from WS3+ [37].

This article is organized as follows. In Section 2, the theoretical framework for calculating α decay half-life is briefly described. The detailed calculations and discussions are presented in Section 3. Finally, a summary is given in Section 4.

2 Theoretical framework

In the TPA, the total interaction potential $V(r)$, between the α particle and daughter nucleus, is composed of the nuclear potential $V_{\rm N}(r)$, Coulomb potential $V_{\rm C}(r)$ and centrifugal potential $V_l(r)$. It can be expressed as

$$V(r)=V_{\rm N}(r)+V_{\rm C}(r)+V_l(r). \tag{1}$$

The nuclear potential is determined within a two-body model. It is assumed that the α particle is preformed at the surface of the parent nucleus and that the strong attractive nuclear interaction can be approximately replaced by a square well potential [32, 50]. In the present work we choose a type of cosh parametrized form for the nuclear potential, which is obtained by analyzing experimental data of α decay [51] and is expressed as

$$V_{\rm N}(r)=-V_0\frac{1+\cosh(R/a_0)}{\cosh(r/a_0)+\cosh(R/a_0)}, \tag{2}$$

where V_0 and a_0 are the depth and diffuseness of the nuclear potential. In our previous work [29], we obtained a set of isospin dependent parameters, a_0=0.5958 fm and $V_0=192.42+31.059\frac{N_{\rm d}-Z_{\rm d}}{A_{\rm d}}$ MeV, where $N_{\rm d}$, $Z_{\rm d}$ and $A_{\rm d}$ are the neutron, proton and mass number of the daughter nucleus, respectively. R, the nuclear potential sharp radius, is calculated empirically within the nuclear droplet model and proximity energy [16] with the mass number of the parent nucleus, A, and is expressed as

$$R=1.28A^{1/3}-0.76+0.8A^{-1/3}. \tag{3}$$

The Coulomb potential $V_{\rm C}(r)$, obtained under the assumption of a uniformly charged sphere with radius R, is expressed as

$$V_{\rm C}(r)=\begin{cases}\dfrac{Z_{\rm d}Z_\alpha e^2}{2R}\left[3-\left(\dfrac{r}{R}\right)^2\right], & r<R,\\ \dfrac{Z_{\rm d}Z_\alpha e^2}{r}, & r>R,\end{cases} \tag{4}$$

where $Z_\alpha=2$ represents the proton number of the α particle. In the present work, we employ the Langer modified centrifugal barrier for $V_l(r)$, because $l(l+1)\to(l+1/2)^2$ is a necessary correction for one-dimensional problems [52]. It can be calculated by

$$V_l(r)=\frac{\hbar^2(l+1/2)^2}{2\mu r^2}, \tag{5}$$

where $\mu=\frac{m_{\rm d}m_\alpha}{m_{\rm d}+m_\alpha}$ denotes the reduced mass between the preformed α particle and daughter nucleus, with $m_{\rm d}$ and m_α being the mass of the daughter nucleus and α particle, respectively. l is the orbital angular momentum taken away by the α particle. $l=0$ for favored α decays, while $l\neq0$ for unfavored decays. Based on the conservation law of angular momentum [53], the minimum angular momentum $l_{\rm min}$ taken away by the α particle can be obtained by

$$l_{\rm min}=\begin{cases}\Delta_j, & \text{for even } \Delta_j \text{ and } \pi_{\rm p}=\pi_{\rm d},\\ \Delta_j+1, & \text{for even } \Delta_j \text{ and } \pi_{\rm p}\neq\pi_{\rm d},\\ \Delta_j, & \text{for odd } \Delta_j \text{ and } \pi_{\rm p}\neq\pi_{\rm d},\\ \Delta_j+1, & \text{for odd } \Delta_j \text{ and } \pi_{\rm p}=\pi_{\rm d},\end{cases} \tag{6}$$

where $\Delta_j=|j_{\rm p}-j_{\rm d}|$, $j_{\rm p}$, $\pi_{\rm p}$, $j_{\rm d}$, $\pi_{\rm d}$ represent spin and parity values of the parent and daughter nuclei, respectively.

The α decay half-life $T_{1/2}$, an important indicator for nuclear stability, is calculated by the decay width Γ or decay constant λ and expressed as

$$T_{1/2}=\frac{\hbar\ln2}{\Gamma}=\frac{\ln2}{\lambda}. \tag{7}$$

In framework of the TPA, Γ can be given by

$$\Gamma=\frac{\hbar^2P_\alpha FP}{4\mu}, \tag{8}$$

where P is the penetration probability, namely the Gamow factor, obtained by the Wentzel-Kramers-Brillouin (WKB) method and expressed as

$$P=\exp\left(-2\int_{r_2}^{r_3}k(r){\rm d}r\right), \tag{9}$$

where $k(r)=\sqrt{\frac{2\mu}{\hbar^2}|Q_\alpha-V(r)|}$ denotes the wave number of the α particle. r is the center of mass distance between the preformed α particle and the daughter nucleus. r_2, r_3 and following r_1 are the classical turning points. They satisfy conditions $V(r_1)=V(r_2)=V(r_3)=Q_\alpha$. The normalized factor F, denoting the assault frequency of the α particle, can be obtained by

$$F\int_{r_1}^{r_2}\frac{1}{2k(r)}{\rm d}r=1. \tag{10}$$

On account of the complicated structure of quantum many-body systems, there are few works [21, 54–57] studying α preformation probabilities P_α from the viewpoint of microscopic theory. Phenomenologically, the α preformation probability P_α is extracted by

$$P_\alpha=P_0\frac{T_{1/2}^{\rm cal}}{T_{1/2}^{\rm exp}}, \tag{11}$$

where $T_{1/2}^{\rm exp}$ denotes experimental half-life. $T_{1/2}^{\rm cal}$ represents the calculated α decay half-life based on the assumption $P_\alpha = P_0$. In accordance with the calculations by adopting the density-dependent cluster model (DDCM) [58], P_0 is 0.43 for even-even nuclei, 0.35 for odd-A nuclei, and 0.18 for doubly-odd nuclei. In the present work, P_0 is 0.35. Recently, the variation tendency of P_α can be estimated by an analytic formula [29, 31, 32, 59, 60], which is considered the nuclear shell structure and proton-neutron interaction, and expressed as

$$\log_{10}P_\alpha = a+b(Z-Z_1)(Z_2-Z)+c(N-N_1)\times(N_2-N)+dA+e(Z-Z_1)(N-N_1), \quad (12)$$

where Z (N) denotes the proton (neutron) number of the parent nucleus. Z_1 (N_1) and Z_2 (N_2) denote the proton (neutron) magic numbers with $Z_1 < Z < Z_2$ and $N_1 < N < N_2$.

3 Results and discussion

In our previous works [29–33], we found that the behavior of α preformation probabilities of the same kinds of nuclei (even-even nuclei, odd-A nuclei and doubly-odd nuclei) in the same region, which is divided by the magic numbers of proton and neutron, can be described by Eq. (12). For the purpose of a precise prediction for ^{297}Og, we systematically study all 64 odd-A nuclei including odd Z, even N (odd-even) and even Z, odd N (even-odd) nuclei in the same region as ^{297}Og, from ^{251}Cf to ^{295}Og. For the odd-A nuclei, excitation of a single nucleon causes high-spin isomers. Our previous studies [30, 33] indicate that both ground and isomeric states can be treated in a unified way for α decay parent and daughter nuclei.

$l_{\rm min}$ is an important input for calculating $T_{1/2}$, and can be calculated by Eq. (6). However, we do not know the spin and parity values of parent nuclei and/or daughter nuclei for α decay of ^{271}Sg, ^{271}Bh, ^{273}Hs and so on. In the present work, the minimum angular momenta are taken as approximately $l_{\rm min} = 0$ for those α decays. To verify whether this assumption is right or not, we plot the logarithm deviation between $T_{1/2}^{\rm pre}$ and $T_{1/2}^{\rm exp}$ for those nuclei in Fig. 1, where $T_{1/2}^{\rm pre}=\frac{P_0 T_{1/2}^{\rm cal}}{P_\alpha^*}$, with P_α^* obtained by Eq. (12) and parameters in Table 1 as well as $T_{1/2}^{\rm cal}$ taking $P_\alpha = P_0$. From Fig. 1, the values of $\log_{10}T_{1/2}^{\rm pre} - \log_{10}T_{1/2}^{\rm exp}$ are, on the whole, around 0. This indicates that the spin and parity of the ground states for those nuclei and their daughter nuclei may be equal. Therefore, the spin and parity of the ground states for ^{269}Sg, ^{285}Fl, and ^{293}Lv may be $3/2^+$, $3/2^+$ and $5/2^+$, respectively. For ^{271}Bh, ^{275}Hs, ^{281}Ds$^{\rm m}$ and ^{295}Og, there are large deviations between the predictions and experimental data. This indicates that the spin and parity of the ground states for the above four nuclei and their daughter nuclei are potentially different.

In the following, we calculate α decay half-lives with $P_\alpha = P_0$ and extract the corresponding P_α using Eq. (11). Then, we fit all the P_α based on Eq. (12) and extract relevant parameters given in Table 1, in the region $82 < Z \le 126$ and $152 < N \le 184$, $Z_1 = 82$, $Z_2 = 126$, $N_1 = 152$, $N_2 = 184$. In our previous work [32], we have obtained a set of parameters for this region. The standard deviation $\sigma_{\rm pre} = \sqrt{\sum(\log_{10}T_{1/2}^{\rm pre} - \log_{10}T_{1/2}^{\rm exp})^2/n}$ denotes deviations of α decay half-life between predictions considering α preformation probability correction and experimental data for those 64 odd-A nuclei. The value of $\sigma_{\rm pre}$ drops from 0.739 when the parameters are taken from Ref. [32] to 0.696 using the new parameters, which indicates that predictions adopting new parameters are improved by $\frac{0.739-0.696}{0.739} = 5.82\%$. The standard deviation $\sigma_{\rm cal} = \sqrt{\sum(\log_{10}T_{1/2}^{\rm cal} - \log_{10}T_{1/2}^{\rm exp})^2/n}$ between the calculated $T_{1/2}$ with $P_\alpha = P_0$ and experimental ones for those 64 odd-A nuclei is 1.177. Hence, by adopting P_α^*, considering the shell effect and proton-neutron interaction, the standard deviation reduces by $\frac{1.177-0.696}{1.177} = 40.87\%$.

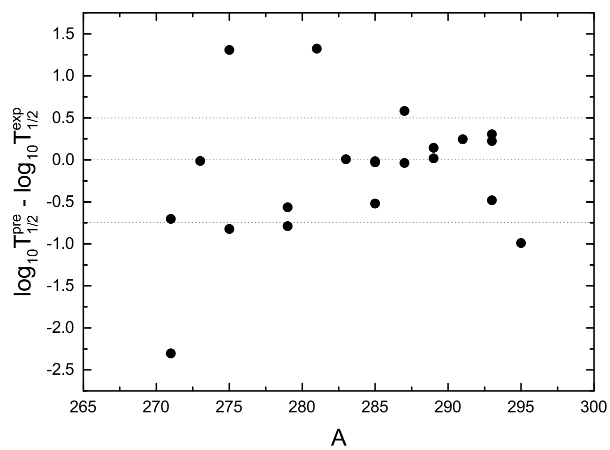

Fig. 1. The logarithmic differences between $T_{1/2}^{\rm pre}$ and $T_{1/2}^{\rm exp}$ for α decay, where the spin and parity of parent and/or daughter nuclei are unknown and we assume $l_{\rm min}=0$.

Table 1. The parameters of P_α^* for odd-A nuclei from $82<Z\le126$ and $152<N\leqslant184$.

a	b	c	d	e
15.4694	-0.0054	-0.0014	-0.0546	0.0019

The detailed calculations are given in Table 2. In this table, the first four columns are the α transition, α decay energy, spin-parity transformation and minimum orbital angular momentum $l_{\rm min}$ taken away by the α particle, respectively. The fifth, sixth and seventh columns are the experimental half-life $T_{1/2}^{\rm exp}$, calculated half-life $T_{1/2}^{\rm cal}$ by TPA with $P_\alpha = P_0$ and extracted α preformation probability P_α with Eq. (11), respectively. The last two ones are α preformation probability P_α^*, and predicted α decay half-lives $T_{1/2}^{\rm pre}$. From Table 2, we find that for some nuclei, such as ^{255}Md, ^{271}Sg, ^{271}Bh, ^{273}Ds$^{\rm m}$, ^{279}Ds, ^{281}Ds and so on, the extracted P_α are especially small. For the case of ^{271}Sg, ^{271}Bh and ^{279}Ds, the reason is that our assumptions of $l_{\rm min}=0$ may be inappropriate. For ^{255}Md, ^{273}Ds$^{\rm m}$ and ^{281}Ds, the uncertain and/or estimated spin and parity may be inaccurate. The inaccuracy $l_{\rm min}$ might cause the great differences between $T_{1/2}^{\rm exp}$ and $T_{1/2}^{\rm cal}$ as well as smaller P_α. The experimental data and predicted results are plotted logarithmically in Fig. 2. From this figure, we can see that the predicted half-lives can reproduce the experimental data well. More intuitively, we plot the difference between the logarithms of predictions and experimental data in Fig. 3. From this figure, we can clearly see that the values of $\log_{10}T_{1/2}^{\rm pre}$–$\log_{10}T_{1/2}^{\rm exp}$ are mainly around zero, indicating that our predictions are in good agreement with the experimental data. Therefore, extending our study to predict the α decay half-life and α preformation probability of nucleus ^{297}Og may be believable. Then we calculate $T_{1/2}$ of ^{297}Og by $T_{1/2}^{\rm pre}=\frac{P_0 T_{1/2}^{\rm cal}}{P_\alpha^*}$ with P_α^* in Table 2, while Q_α is taken from WS3+ [37] and $l_{\rm min}=0$. Finally, according to the standard deviations, $\sigma_{\rm pre}$ for the 64 odd-A nuclei in the same region as ^{297}Og, is 0.696, and the predicted α decay half-life of ^{297}Og is 0.16 ms within a factor of 4.97.

Table 2. Calculations of α decay half-lives and α preformation probabilities and predicted half-lives. Elements with upper suffixes 'm', 'n' and 'p' indicate assignments to excited isomeric states (defined as higher states with half-lives greater than 100 ns). Suffixes 'p' also indicate non-isomeric levels, but used in the AME2016 [48, 49]. '()' means uncertain spin and/or parity. '#' means values estimated from trends in neighboring nuclides with the same Z and N parities.

α transition	Q_α/MeV	$j_{\rm p}^\pi \to j_{\rm d}^\pi$	$l_{\rm min}$	$T_{1/2}^{\rm exp}$/s	$T_{1/2}^{\rm cal}$/s	P_α	P_α^*	$T_{1/2}^{\rm pre}$/s
^{251}Cf $\to ^{247}$Cm$^{\rm n}$	5.77	$1/2^+ \to 1/2^+$	0	2.84×10^{10}	3.38×10^{10}	0.42	0.22	5.50×10^{10}
^{253}Cf $\to ^{249}$Cm$^{\rm m}$	6.08	$(7/2^+)\to(7/2^+)$	0	4.96×10^{8}	6.37×10^{8}	0.45	0.16	1.39×10^{9}
^{255}Cf $\to ^{251}$Cm	5.74	$(7/2^+)\to(1/2^+)$	4	2.55×10^{12}	2.69×10^{11}	0.04	0.12	7.64×10^{11}
^{253}Es $\to ^{249}$Bk	6.74	$7/2^+ \to 7/2^+$	0	1.77×10^{6}	1.11×10^{6}	0.22	0.14	2.70×10^{6}
^{255}Es $\to ^{251}$Bk$^{\rm m}$	6.40	$(7/2^+)\to 7/2^+\#$	0	4.28×10^{7}	4.09×10^{7}	0.33	0.11	1.30×10^{8}
^{253}Fm $\to ^{249}$Cf$^{\rm m}$	7.05	$(1/2)^+ \to 5/2^+$	2	2.14×10^{6}	2.24×10^{5}	0.04	0.13	5.97×10^{5}
^{257}Fm $\to ^{253}$Cf	6.86	$(9/2^+)\to(7/2^+)$	2	8.68×10^{6}	1.26×10^{6}	0.05	0.08	5.65×10^{6}
^{255}Md $\to ^{251}$Es	7.91	$(7/2^-)\to 3/2^-$	2	2.28×10^{4}	2.41×10^{2}	3.70×10^{-3}	0.09	9.06×10^{2}
^{257}Md $\to ^{253}$Es	7.56	$(7/2^-)\to 7/2^+$	1	1.30×10^{5}	3.15×10^{3}	0.01	0.07	1.52×10^{4}
^{259}Md $\to ^{255}$Es	7.11	$7/2^-\#\to(7/2^+)$	1	4.43×10^{5}	2.01×10^{5}	0.16	0.06	1.22×10^{6}
^{255}No $\to ^{251}$Fm$^{\rm m}$	8.23	$(1/2^+)\to 5/2^+$	2	6.92×10^{2}	4.53×10^{1}	0.02	0.09	1.78×10^{2}
^{259}No $\to ^{255}$Fm	7.85	$(9/2^+)\to 7/2^+$	2	4.62×10^{3}	8.13×10^{2}	0.06	0.05	5.21×10^{3}
^{257}Lr $\to ^{253}$Md$^{\rm p}$	9.02	$(1/2^-)\to 1/2^-\#$	0	6.00×10^{0}	1.84×10^{-1}	0.01	0.07	9.66×10^{-1}
^{259}Lr $\to ^{255}$Md$^{\rm p}$	8.58	$1/2^-\#\to 1/2^-\#$	0	7.93×10^{0}	3.95×10^{0}	0.17	0.05	2.62×10^{1}
^{257}Rf$^{\rm m} \to ^{253}$No	9.16	$(11/2^-)\to(9/2^-)$	2	4.88×10^{0}	2.72×10^{-1}	0.02	0.07	1.44×10^{0}
^{259}Rf $\to ^{255}$No$^{\rm p}$	9.03	$7/2^+\#\to(7/2^+)$	0	2.85×10^{0}	3.73×10^{-1}	0.05	0.05	2.50×10^{0}
^{261}Rf $\to ^{257}$No	8.65	$3/2^+\#\to(3/2^+)$	0	7.97×10^{0}	5.18×10^{0}	0.23	0.04	4.30×10^{1}
^{263}Rf $\to ^{259}$No	8.26	$3/2^+\#\to(9/2^+)$	4	2.20×10^{3}	5.28×10^{2}	0.08	0.03	5.28×10^{3}
^{259}Db $\to ^{255}$Lr$^{\rm m}$	9.58	$9/2^+\#\to(7/2^-)$	1	5.10×10^{-1}	2.58×10^{-2}	0.02	0.05	1.71×10^{-1}
^{259}Sg $\to ^{255}$Rf	9.77	$(11/2^-)\to(9/2^-)$	2	4.14×10^{-1}	2.51×10^{-2}	0.02	0.05	1.60×10^{-1}
^{259}Sg$^{\rm m} \to ^{255}$Rf$^{\rm m}$	9.71	$(1/2^+)\to(5/2^+)$	2	2.33×10^{-1}	3.67×10^{-2}	0.06	0.05	2.35×10^{-1}
^{261}Sg $\to ^{257}$Rf	9.71	$(3/2^+)\to(1/2^+)$	2	1.86×10^{-1}	3.18×10^{-2}	0.06	0.04	2.54×10^{-1}
^{263}Sg $\to ^{259}$Rf	9.41	$7/2^+\#\to 7/2^+\#$	0	1.07×10^{0}	1.32×10^{-1}	0.04	0.04	1.28×10^{0}
^{265}Sg $\to ^{261}$Rf$^{\rm m}$	8.98	$9/2^+\#\to 9/2^+\#$	0	1.84×10^{1}	2.37×10^{0}	0.05	0.03	2.74×10^{1}
^{265}Sg$^{\rm m} \to ^{261}$Rf	9.12	$3/2^+\#\to 3/2^+\#$	0	2.52×10^{1}	8.75×10^{-1}	0.01	0.03	1.01×10^{1}
^{271}Sg $\to ^{267}$Rf	8.90		0	2.66×10^{2}	3.20×10^{0}	4.22×10^{-3}	0.02	5.27×10^{1}
^{261}Bh $\to ^{257}$Db$^{\rm m}$	10.36	$(5/2^-)\to(1/2^-)$	2	1.34×10^{-2}	1.45×10^{-3}	0.04	0.05	1.10×10^{-2}
^{271}Bh $\to ^{267}$Db	9.43		0	6.00×10^{2}	1.88×10^{-1}	1.09×10^{-4}	0.02	2.99×10^{0}
^{265}Hs $\to ^{261}$Sg	10.47	$3/2^+\#\to(3/2^+)$	0	1.96×10^{-3}	8.53×10^{-4}	0.15	0.03	8.78×10^{-3}
^{265}Hs$^{\rm m} \to ^{261}$Sg$^{\rm m}$	10.60	$9/2^+\#\to(11/2^-)$	1	3.60×10^{-4}	4.90×10^{-4}	0.48	0.03	5.05×10^{-3}
^{267}Hs $\to ^{263}$Sg	10.04	$5/2^+\#\to 7/2^+\#$	2	6.88×10^{-2}	1.67×10^{-2}	0.09	0.03	2.01×10^{-1}
^{269}Hs $\to ^{265}$Sg	9.35	$9/2^+\#\to 9/2^+\#$	0	1.60×10^{1}	8.45×10^{-1}	0.02	0.03	1.15×10^{1}
^{273}Hs $\to ^{269}$Sg	9.71	$3/2^+\#\to$	0	1.06×10^{0}	6.32×10^{-2}	0.02	0.02	1.03×10^{0}
^{275}Hs $\to ^{271}$Sg	9.44		0	2.90×10^{-1}	3.45×10^{-1}	0.42	0.02	5.90×10^{0}
^{275}Mt $\to ^{271}$Bh	10.49		0	1.17×10^{-1}	1.10×10^{-3}	3.30×10^{-3}	0.02	1.76×10^{-2}

Continued on next page

Table 2. – continued from previous page

α transition	Q_α/MeV	$j_p^\pi \to j_d^\pi$	l_{min}	$T_{1/2}^{exp}$/s	$T_{1/2}^{cal}$/s	P_α	P_α^*	$T_{1/2}^{pre}$/s
^{267}Ds →^{263}Hs	11.78	3/2+#→3/2+#	0	1.00×10^{-5}	3.73×10^{-6}	0.13	0.04	3.69×10^{-5}
^{269}Ds →^{265}Hs^m	11.28	9/2+#→9/2+#	0	2.30×10^{-4}	4.08×10^{-5}	0.06	0.03	4.62×10^{-4}
^{271}Ds →^{267}Hs	10.88	13/2−#→5/2/+#	5	9.00×10^{-2}	3.25×10^{-3}	0.01	0.03	4.10×10^{-2}
^{271}Ds^m→^{267}Hs	10.95	9/2+#→5/2+#	2	1.70×10^{-3}	3.46×10^{-4}	0.07	0.03	4.38×10^{-3}
^{273}Ds →^{269}Hs	11.38	13/2−#→9/2+#	3	2.40×10^{-4}	5.10×10^{-5}	0.07	0.03	7.01×10^{-4}
^{273}Ds^m→^{269}Hs	11.58	3/2+#→9/2+#	4	1.20×10^{-1}	3.44×10^{-5}	1.00×10^{-4}	0.03	4.72×10^{-4}
^{277}Ds →^{273}Hs	10.83	11/2+#→3/2+#	4	6.00×10^{-3}	1.50×10^{-3}	0.09	0.02	2.25×10^{-2}
^{279}Ds →^{275}Hs	10.09		0	2.10×10^{0}	2.26×10^{-2}	3.77×10^{-3}	0.02	3.42×10^{-1}
^{281}Ds →^{277}Hs	9.52	3/2+#→3/2+#	0	9.26×10^{1}	8.49×10^{-1}	3.21×10^{-3}	0.02	1.26×10^{1}
^{281}Ds^m→^{277}Hs^m	9.46		0	9.00×10^{-1}	1.28×10^{0}	0.50	0.02	1.90×10^{1}
^{279}Rg →^{275}Mt	10.53		0	1.80×10^{-1}	3.60×10^{-3}	0.01	0.03	4.90×10^{-2}
^{277}Cn →^{273}Ds^m	11.42	3/2+#→3/2+#	0	8.50×10^{-4}	6.13×10^{-5}	0.03	0.03	7.24×10^{-4}
^{281}Cn →^{277}Ds	10.46	3/2+#→11/2+#	4	1.80×10^{-1}	5.13×10^{-2}	0.10	0.03	6.07×10^{-1}
^{285}Cn →^{281}Ds	9.32	5/2+#→3/2+#	2	3.20×10^{1}	2.62×10^{1}	0.29	0.03	2.81×10^{2}
^{285}Cn^m→^{281}Ds^m	9.85		0	1.50×10^{1}	4.22×10^{-1}	0.01	0.03	4.52×10^{0}
^{283}Ed →^{279}Rg	10.51		0	1.60×10^{-1}	1.64×10^{-2}	0.04	0.04	1.63×10^{-1}
^{285}Ed →^{281}Rg	10.01		0	3.30×10^{0}	3.42×10^{-1}	0.04	0.04	3.19×10^{0}
^{285}Fl →^{281}Cn	10.56	→3/2+#	0	2.10×10^{-1}	2.48×10^{-2}	0.04	0.04	1.97×10^{-1}
^{287}Fl →^{283}Cn	10.16		0	5.20×10^{-1}	2.71×10^{-1}	0.18	0.05	1.99×10^{0}
^{289}Fl →^{285}Cn	9.97	5/2+#→5/2+#	0	2.40×10^{0}	8.52×10^{-1}	0.12	0.05	5.62×10^{0}
^{289}Fl^m→^{285}Cn^m	10.17		0	1.10×10^{0}	2.33×10^{-1}	0.07	0.05	1.53×10^{0}
^{287}Ef →^{283}Ed	10.77		0	9.50×10^{-2}	1.43×10^{-2}	0.05	0.06	8.76×10^{-2}
^{289}Ef →^{285}Ed	10.52		0	3.10×10^{-1}	5.86×10^{-2}	0.07	0.06	3.24×10^{-1}
^{291}Lv →^{287}Fl	10.90		0	2.80×10^{-2}	1.23×10^{-2}	0.15	0.09	4.92×10^{-2}
^{293}Lv →^{289}Fl	10.69	→5/2+#	0	8.00×10^{-2}	3.88×10^{-2}	0.17	0.10	1.34×10^{-1}
^{293}Lv^m→^{289}Fl^m	10.66		0	8.00×10^{-2}	4.67×10^{-2}	0.20	0.10	1.61×10^{-1}
^{293}Eh →^{289}Ef	11.30		0	2.10×10^{-2}	2.48×10^{-3}	0.04	0.13	6.93×10^{-3}
^{293}Og→^{289}Lv	11.92	1/2+#→5/2+#	2	1.00×10^{-3}	2.96×10^{-4}	0.10	0.16	6.53×10^{-4}
^{295}Og→^{291}Lv	11.70		0	1.00×10^{-2}	5.49×10^{-4}	0.02	0.19	1.03×10^{-3}
^{297}Og→^{293}Lv^m	12.00		0		1.04×10^{-4}		0.23	1.60×10^{-4}

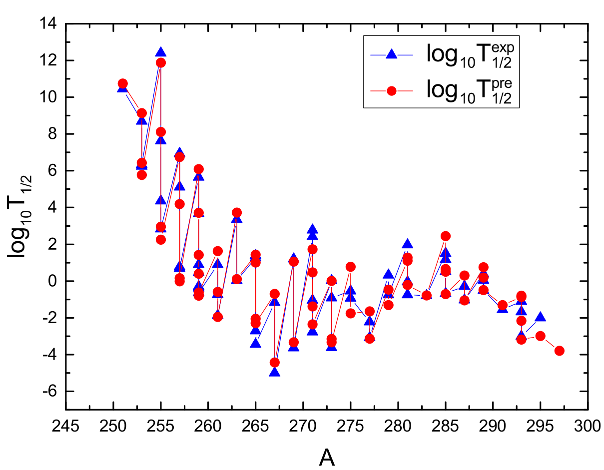

Fig. 2. (color online) Logarithmic half-lives of experimental and predicted data. The blue triangles and red circles denote the experimental half-lives $T_{1/2}^{exp}$ and predicted results $T_{1/2}^{pre}$, respectively.

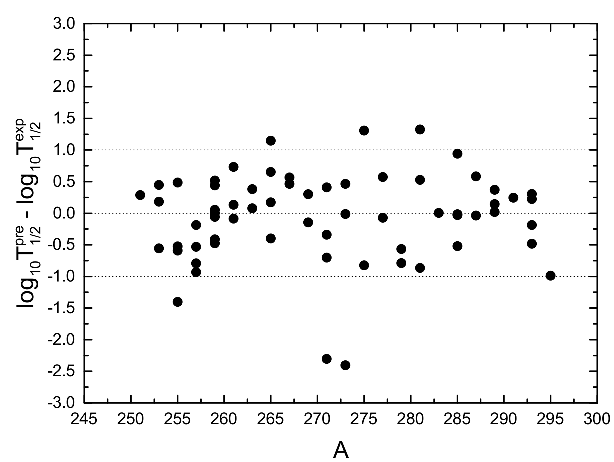

Fig. 3. The logarithmic differences between $T_{1/2}^{pre}$ and $T_{1/2}^{exp}$.

4 Summary

In summary, we predict the α decay half-life of ^{297}Og, and systematically calculate the half-lives of 64 odd-A nuclei in the region $82<Z<126$ and $152<N<184$, from ^{251}Cf to ^{295}Og, within the TPA. We also extract corresponding α preformation probabilities and a new set of parameters for α preformation probabilities considering the shell effect and proton-neutron interaction. The spin and parity of the ground states for ^{269}Sg, ^{285}Fl, ^{293}Lv are predicted to be $3/2^+$, $3/2^+$ and $5/2^+$, respectively. The predicated $T_{1/2}$ of ^{297}Og is 0.16 ms within a factor of 4.97. This work will be useful as a reference for synthesizing ^{297}Og.

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