Alpha-Decay Chains of Superheavy Nuclei with Z = 121

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To look for the possible fusion reactions and to detect superheavy nuclei specially with Z > 118, is one of the eminent problems in the current nuclear physics world. So far many superheavy nuclei upto Z = 118, have been produced either by cold fusion reaction with target ^{208}Pb and ^{209}Bi at GSI Germany [1] and RIKEN Japan [2] or by hot fusion with projectile ^{48}Ca at JINR Dubna, Russia [3–5]. However, for Z > 118, few attempts were already made [6, 7] and the further information in this direction by many experimental and theoretical investigations are highly welcomed.

In view of this, we investigate even and odd isotopes of Z = 121 (298 ≤ A ≤ 302) using relativistic mean-field plus state dependent BCS (RMF+BCS) approach [8, 9] and try to dig int possible α-decay chains for the identification of new element. We compare our results with available experimental data [10]. Investigation of decay properties viz. α-decay and spontaneous fission (SF), have been found as the best and dominant way to probe superheavy nuclei and their stability for the identification of new elements. Out of which α-decay is found as a very powerful tool to investigate the nuclear structure properties of superheavy nuclei. We have studied alpha decay chain of $^{298-302}$121 and calculated alpha decay half-lives and spontaneous half-lives of decay chain of these nuclei. For this study, α-decay half-lives are calculated by using most recent modified Royer formula given by Akrawy *et al* in 2017 [11]:

$$log_{10}T_\alpha(sec) = a + bA^{1/6}\sqrt{Z} + \frac{cZ}{\sqrt{Q_\alpha}} + dI + eI^2 \quad (1)$$

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where I = $\frac{N-Z}{A}$ and the constants a, b, c, d, and e are

(Z-N)	a	b	c	d	e
$e-e$	-27.837	-0.9420	1.5343	-5.7004	8.785
$o-e$	-26.801	-1.1078	1.5585	14.8525	-30.523
$e-o$	-28.225	-0.8629	1.5377	-21.145	53.890
$o-o$	-23.635	-0.891	1.404	-12.4255	36.9005

The spontaneous fission half-life T_{SF} is calculated using the semiempirical formula proposed by Xu *et al.* taken from Ref. [12].

$$T_{1/2} = exp[2\pi\{C_0 + C_1A + C_2Z^2 + C_3Z^4 + C_4(N-Z)^2 - (0.13323\frac{Z^2}{A^{1/3}} - 11.64)\}] \quad (2)$$

The constants are C_0 = -195.09227, C_1 = 3.10156, C_2 = -0.04386, C_3 = 1.4030 x 10^{-6}, and C_4 = -0.03199. We use this formula for even-even isotopes and then take average to calculate spontaneous fission half life for odd isotopes.

Table 1 shows the calculated values of α-decay half-life (T_α), spontaneous fission half-life (T_{SF}) and the possible decay mode which could be either α decay or SF. We have also compared Q_α, α-decay half-life (T_α) as well as the decay mode with the available experimental data taken from Ref. [4]. It may be noted from Table 1 that these chains of nuclei with Z = 121, are found with long α-decay chain for which our calculated α-decay half-life and predicted decay mode are in excellent agreement with available data from experiments [4].

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TABLE I: Comparison of Q_α values, α-decay half-lives calculated by using modified Royer formula [11] and possible mode of decay of Z = 121 α-decay chains with available experimental data [4].

Nuclei	Q_α(MeV)		$T_\alpha(1/2)$(sec)		Decay Mode	
	RMF	Expt.	RMF	Expt.	RMF	Expt.
^{298}121	12.81		2.91×10^{-03}		α1	
^{294}119	11.29		9.74×10^{-01}		α2	
^{290}Ts	10.82		$3.04\times10^{+00}$		α3	
^{286}Mc	11.87		4.93×10^{-03}		α4	
^{282}Nh	11.27	10.78±0.08	2.30×10^{-02}	7.3×10^{-02}	α5	α
^{278}Rg	10.49	10.85±0.08	3.06×10^{-01}	4.2×10^{-03}	α6	α
^{274}Mt	9.85	10.20±1.10	$2.68\times10^{+00}$	4.4×10^{-01}	α7/SF	α
^{299}121	12.42		8.14×10^{-04}		α1	
^{295}119	11.17		1.73×10^{-01}		α2	
^{291}Ts	10.72		6.25×10^{-01}		α3	
^{287}Mc	11.21	10.76±0.05	9.20×10^{-03}	3.7×10^{-02}	α4	α
^{283}Nh	11.00	10.23±0.01	7.54×10^{-03}	7.5×10^{-02}	α5	α
^{279}Rg	10.52	10.38±0.16	2.89×10^{-02}	9.0×10^{-02}	α6	α
^{275}Mt	10.90	10.48±0.01	8.67×10^{-04}	2.0×10^{-02}	α7	α
^{300}121	12.76		3.42×10^{-03}		α1	
^{296}119	11.11		$2.42\times10^{+00}$		α2	
^{292}Ts	10.93		$1.65\times10^{+00}$		α3	
^{288}Mc	10.13	10.63±0.01	$3.44\times10^{+01}$	1.64×10^{-01}	α4	α
^{284}Nh	10.82	10.12±0.01	2.01×10^{-01}	9.1×10^{-03}	α5	α
^{280}Rg	10.43	9.91±0.01	4.10×10^{-01}	$4.6\times10^{+00}$	SF	α
^{276}Mt	9.99	10.03±0.01	$1.18\times10^{+00}$	4.5×10^{-01}	SF	α
^{301}121	12.33		1.25×10^{-03}		α1	
^{297}119	10.86		$1.02\times10^{+00}$		α2	
^{293}Ts	10.91	11.32±0.05	1.87×10^{-01}	2.2×10^{-02}	α3	α
^{289}Mc	10.01	10.49±0.05	$1.12\times10^{+01}$	3.3×10^{-02}	α4	α
^{285}Nh	10.30	10.01±0.04	$1.19\times10^{+00}$	$4.2\times10^{+00}$	α5/SF	α
^{281}Rg	10.37	9.41±0.05	6.83×10^{-02}	$1.7\times10^{+01}$	SF	SF
^{277}Mt	10.85		1.08×10^{-03}	5.0×10^{-03}	SF	SF
^{302}121	12.59		6.90×10^{-03}		α1	
^{298}119	10.58		$4.11\times10^{+01}$		α2	
^{294}Ts	10.75	11.18±0.04	$4.16\times10^{+00}$	5.1×10^{-02}	α3	α
^{290}Mc	10.27	10.41±0.04	$1.49\times10^{+01}$	6.5×10^{-01}	α4	α
^{286}Nh	9.33	9.79±0.05	$1.04\times10^{+03}$	$9.5\times10^{+00}$	SF	α
^{282}Rg	9.98	9.16±0.03	$4.94\times10^{+00}$	$10.0\times10^{+01}$	SF	α
^{278}Mt	9.93	9.58±0.03	$1.56\times10^{+00}$	$4.5\times10^{+00}$	SF	α

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