Calculations of α decay half lives of the new element Z=117 using FSUGold force

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Introduction

The detection of α-decay chains of superheavy nuclei (SHN) is the main tool to extract some information regarding their degree of stability and possible existence in nature. In the last decade several theoretical and experimental works were devoted to the formation of SHN and their α-decay half-lives (τ_α). In this paper, our primary aim is to check the stability of recently discovered [1] new superheavy element with atomic number Z=117 against α-decay. The two new isotopes ^{293}117 and ^{294}117 are recently produced along with 9 more new nuclei as their decay products at JINR, Dubna [1] in fusion reaction between ^{48}Ca and ^{249}Bk.

Calculations of α-decay half lives

In our previous works [2] we showed the applicability of our calculation using DDM3Y interaction in predicting the τ_α of SHN from a direct comparison with the experimental data. In this paper, we calculate the τ_α of some recently observed SHN. The density distribution of α-particle and daughter nuclei are determined from the relativistic mean field theory (RMF) using FSUGold force, NL3 and TM1 parameteter sets. The RMF theory has successfully described various properties of nuclei from light to superheavy domain. In the $\sigma-\omega$ mean field model [3], the baryon and meson fields interact via exchange of scalar (σ) and vector (ω) mesons which produce strong attraction and repulsion respectively. Later, the $\sigma-\omega$ model was improved by adding isovector ρ-mesons which couple to the isovector current and photons to produce the well-known electromagnetic interaction. In this work, we determine the density distributions of emitter and daughter nuclei from RMF calculations using three different parameter sets namely, FSUGold force, NL3 and TM1. The half lives of α disintegration processes are calculated using the WKB approximation for barrier penetrability. Spherical charge distributions have been used for calculating the Coulomb interaction potentials.

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Results and discussions

In Table 1, the calculated and experimental α-decay half lives are given for 3 and 6 isotopes of the newly discovered ^{293}117 and ^{294}117 nuclei respectively. Most of the experimental Q-values of α decay (Q_α) are obtained from measured α-decay energies in the experiments at JINR, Dubna. We have taken density distributions from RMF calculations instead of assuming a spherically symmetric phenomenological density distribution previously used by Roy Chowdhury *et al* [2]. This makes our calculation more microscopic in nature. Moreover in Table 1, we have given a comparison among the estimates of half lives using three different parameter sets. It is clear from the table that in most of the cases calculated half lives from RMF density distributions using FSUGold force, NL3 and TM1 do not differ much. To remove the discrepancy between experimental and calculated half lives (e.g. see Table 1 for ^{290}115, ^{282}111, ^{274}107 nuclei) more data with higher statistics are needed. Interestingly, we see reasonable agreement for such nuclei with the calculation using estimated E_α [4] (shown by $\star$ symbol in the table) mentioned in the text of Ref.[1]. As the calculation is very sensitive to Q_α, slight difference in values of Q_α makes significantly changes in half lives.

TABLE I: Comparisons between observed and calculated (this work) α-decay half lives ($\tau^{M3Y}_{FSUGold}$, τ^{M3Y}_{NL3} and τ^{M3Y}_{TM1}) using measured Q_α. The experimental α-decay half lives (τ^{EXP}) are taken from Ref.[1] except the values with single (*) asterisk symbols which are taken from Ref. [4] respectively.

Parent	Ref. [1]	Ref. [1]	Half lives	Half lives	Half lives	Half lives
^AZ	E^{expt}_α (MeV)	Q_α (MeV)	τ^{EXP} Ref.[1]	$\tau^{M3Y}_{FSUGold}$	τ^{M3Y}_{NL3}	τ^{M3Y}_{TM1}
$^{293}117$	11.03 (8)	11.19 (8)	21 ms	$4.1^{+2.3}_{-1.5}$ ms	$3.5^{+2.1}_{-1.2}$ ms	$3.6^{+2.1}_{-1.3}$ ms
$^{293}117$	*11.26	11.42	*10 ms	1.2 ms	1.0 ms	1.0 ms
$^{289}115$	10.31 (9)	10.46 (9)	0.32 s	65^{+47}_{-27} ms	56^{+40}_{-24} ms	57^{+41}_{-24} ms
$^{289}115$	*10.48	10.63	*0.22 s	23 ms	20 ms	20 ms
$^{285}113$	9.48 (11)	9.62 (11)	7.9 s	$3.0^{+3.4}_{-1.6}$ s	$2.6^{+2.8}_{-1.4}$ s	$2.6^{+3.2}_{-1.4}$ s
$^{285}113$	9.74 (8)	9.89 (8)	7.9 s	530^{+366}_{-213} ms	456^{+312}_{-184} ms	464^{+317}_{-187} ms
$^{285}113$	*9.96	10.11	*1.2 s	0.13 s	0.11 s	0.11 s
$^{294}117$	10.81 (10)	10.97 (10)	112 ms	52^{+46}_{-23} ms	45^{+39}_{-20} ms	48^{+38}_{-22} ms
$^{294}117$	*11.00	11.16	*45 ms	18 ms	15 ms	16 ms
$^{290}115$	9.95 (40)	10.10 (10)	0.023 s	$2.43^{+33.18}_{-2.24}$ s	$2.09^{+28.41}_{-1.93}$ s	$2.13^{+28.89}_{-1.96}$ s
$^{290}115$	*10.23	10.38	*1.0 s	0.40 s	0.34 s	0.35 s
$^{286}113$	9.63 (10)	9.77 (10)	28.3 s	$4.2^{+4.0}_{-2.0}$ s	$3.6^{+3.4}_{-1.8}$ s	$3.6^{+3.5}_{-1.7}$ s
$^{286}113$	*9.56	9.70	*16 s	6.7 s	5.7 s	5.8 s
$^{282}111$	9.00 (10)	9.13 (10)	0.74 s	$70.1^{+77.3}_{-35.9}$ s	$59.95^{+66.01}_{-30.79}$ s	$60.91^{+67.05}_{-31.27}$ s
$^{282}111$	*9.43	9.57	*8.1 s	3.4 s	2.9 s	3.0 s
$^{278}109$	9.55 (19)	9.70 (19)	11.0 s	$0.3^{+0.8}_{-0.2}$ s	$0.3^{+0.6}_{-0.2}$ s	$0.3^{+0.7}_{-0.2}$ s
$^{278}109$	*9.14	9.28	*13 s	5.0 s	4.3 s	4.3 s
$^{274}107$	8.80 (10)	8.94 (10)	1.3 min	$11.3^{+12.1}_{-5.9}$ s	$9.6^{+10.4}_{-5.0}$ s	$9.7^{+10.5}_{-5.0}$ s
$^{274}107$	*8.43	8.56	*7.4 min	3.02 min	2.57 min	2.62 min

Summary and Conclusion

The α-decay half lives of SHN are calculated in a quantum tunneling model with DDM3Y effective nuclear interaction using theoretical and measured Q_α values. We determine the density distribution of α and daughter nuclei from the RMF using FSUGold force, NL3 and TM1 parameteter sets. The double folded nuclear potential are numerically calculated in a more microscopic manner using these density distribution. For most of the SHN, the estimated values of α-decay half-lives are in reasonable agreement with the recent data.

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References

[1] Yu. Ts. Oganessian *et al*; Phys. Rev. Lett. **104**, 142502 (2010).

[2] P. Roy Chowdhury *et al*; Phys. Rev. C **77**, 044603 (2008); Atom. Dat. Nucl. Dat. Tables **94**, 781 (2008).

[3] B. D. serot and J. D. Walecka, Adv. Nucl. Phys. **16**, 1 (1986)

[4] A. Sobiczewski, Acta Phys. Pol. B **41**, 157 (2010).