Alpha decay properties of $^{293, 294}$Ts

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Introduction

Superheavy nuclei (SHN) and their decay properties is one of the fast developing fields in nuclear physics. With the advancements in experimental techniques, elements up to Z = 118 (Og) have been synthesized yet. Studies on the alpha decay properties of superheavy are very important because the newly synthesized isotopes can be identified via their alpha decay chains.

In the present paper the alpha decay properties of the two experimentally synthesized isotopes of Tennesssine (Z = 117), ^{293}Ts and ^{294}Ts are studied. The alpha half-lives of the isotopes are calculated using the modified generalized liquid drop model (MGLDM) [1]. The calculated half-lives are then compared with several other theoretical models and also with the experimental results.

The Model

The macroscopic energy for a deformed nucleus according to GLDM is given as,

$$E = E_V + E_S + E_C + E_R + E_P \quad . \qquad (1)$$

Here the terms E_v, E_s, E_c, E_R and E_P represents the volume, surface, Coulomb, rotational and proximity energy terms respectively. Separate equations are used for pre-scission region and post-scission region in the case of volume, surface and Coulomb energies as given in Ref [1]. The nuclear proximity potential given by Blocki et al. [2] is used for the term E_P.

The barrier penetrability P is calculated using the action integral,

$$\mathrm{P} = \exp\left\{ -\frac{2}{\hbar} \int_{R_{in}}^{R_{out}} \sqrt{2B(r)[E(r) - E(sphere)]}\, dr \right\} . \qquad (2)$$

Here $R_{in} = R_1 + R_2$, $B(r) = \mu$ and $R_{out} = e^2 Z_1 Z_2 / Q$. R_1, R_2 are the radius of the daughter nuclei and emitted alpha particle respectively. μ and Q represents the reduced mass and the decay energy. The half-life for the decay is given by,

$$T_{1/2} = \left(\frac{\ln 2}{\lambda} \right) = \left(\frac{\ln 2}{\nu P} \right) \qquad (3)$$

The assault frequency ν has been taken as 10^{20} s^{-1}.

Results and Discussions

The alpha decay energies and half-lives of the two experimentally synthesized isotopes, ^{293}Ts and ^{294}Ts are studied.

The Q values and half-lives for the isotope ^{293}Ts is given in Table 1.

Table 1: Predictions on the alpha decay half-lives of ^{293}Ts and its daughter nuclei

Parent Nuclei	Q_{exp} **(MeV)**	$T^{\alpha}_{1/2}$ **(s)**	
		Expt.	**MGLDM**
^{293}Ts	11.180	1.400E-02	7.380E-03
^{289}Mc	10.450	2.200E-01	1.498E-01
^{285}Nh	9.880	5.500E+00	1.438E+00
^{281}Rg	9.950*		2.066E-01
^{277}Mt	9.958*		4.531E-02
^{273}Bh	9.157*		2.290E+00
^{269}Db	8.545*		4.538E+01
^{265}Lr	7.274*		5.584E+05
^{261}Md	6.802*		1.062E+07
^{257}Es	6.091*		5.113E+09

*Q value calculated using the mass excesses taken from AME2020 [3]

The experimental Q values and half-lives are taken from Ref [4]. The matching between theoretical prediction and the experimental data is evident from the table. For a theoretical comparison, the alpha decay half-lives are calculated using the CPPM, the VSS formula, the analytical formula of Royer and UDL. Figure 1 gives the comparison of theoretical predictions with the experimental data.

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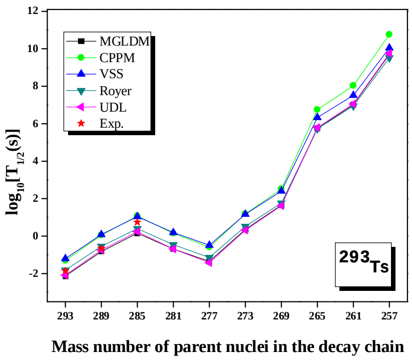

Fig. 1 alpha decay chain for the isotope ^{293}Ts using different models

Similar calculations are done for the isotope ^{294}Ts and the results are displayed in Table 2.

Table 2: Predictions on the alpha decay half-lives of ^{294}Ts and its daughter nuclei

Parent Nuclei	Q_{exp} (MeV)	$T_{1/2}^{\alpha}$ (s)	
		Expt.	MGLDM
^{294}Ts	10.960	7.800E-02	2.570E-02
^{290}Mc	10.090	1.600E-02	1.477E+00
^{286}Nh	9.760	2.000E+01	3.130E+00
^{282}Rg	9.130	5.100E-01	6.186E+01
^{278}Mt	9.690	7.700E+00	2.524E-01
^{274}Bh	8.930	5.300E+01	1.159E+01
^{270}Db	8.365*		1.831E+02
^{266}Lr	7.614*		2.105E+04
^{262}Md	6.592*		1.025E+08
^{258}Es	5.931*		3.751E+10

*Q value calculated using the mass excesses taken from AME2020 [3]

In the case of ^{294}Ts also, we can see a reasonable agreement with the theoretical and experimental observations. The comparisons of the results with other theoretical formalisms are given in Figure 2. The agreement between half-lives using MGLDM and other theoretical models is clear from the study.

While we calculate the standard deviation, it is evident that the half-lives calculated using MGLDM deviates less from the experimental results as compared to other theoretical models. The estimated standard deviation of MGLDM is 1.233.

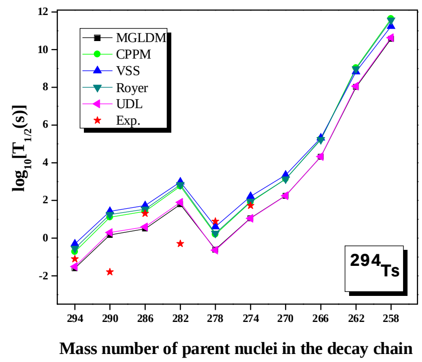

Fig. 2 alpha decay chain for the isotope ^{294}Ts using different models

Conclusions

The Q values and half-lives of the two experimentally synthesized isotopes ^{293}Ts and ^{294}Ts are presented in the study. The half-lives are calculated using MGLDM and are compared with the experimental results and other theoretical models. It is seen that the results obtained with MGLDM is in good agreement with the experimental results than the other theoretical models. It emphasizes the applicability of MGLDM in superheavy region. Also the calculated half-lives are well within the experimental limit, which indicates that these isotopes and their daughter nuclei will have a good chance to observe in laboratories via alpha decay chain.

References

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