Model dependant Q-value for α-decay

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The heavy ion reactions with suitable projectile and target combinations have contributed and still contribute immensely towards the production and study of the new nucleides at various research laboratories. The heaviest element with proton number $Z = 118$ has been reported. It is still being investigated (Please see Ref. 1 of [1], using ^{251}Cf(^{48}Ca,3n) ^{296}Og reaction) at Dubna.

Two α-decay chains starting from $^{296}_{118}$Og and $^{294}_{118}$Og have been analyzed in detail recently by Sobiczeswski [1]. The input required in the calculations are decay Q-values and the model for calculating the corresponding half-lives. The reference [1] uses various Q-values obtained by using different methods including the experimental values. The phenomenological analytic expression is used for the calculation of decay lives.

Here, we use an analytic expression based on the Liquid Drop Model with a few (two) parameters (Sahu+YKG to be published) for the Q-values which reproduces the corresponding experimental Q-values extremely well (maximum deviation being 300 keV).

In addition, we use an analytic expression derived by Sahu and Bhoi [2] for the calculation of decay half lives. We present the expression for the decimal logarithm of decay half life below.

Half-lives of radioactive nuclei decaying by the emission of α particles can be estimated by analyzing the resonance activity in the collision of the α+daughter nucleus system. For a typical α+nucleus system, the mass numbers of the α particle and the daughter nucleus are represented by A_α and A_D and the proton numbers are denoted by Z_α and Z_D, respectively. With their characteristic centre-mass-energy $E_{c.m.}=Q_\alpha$ value, the wave number is given by $k= \sqrt{2\mu E_{c.m.}}/\hbar$, $\mu = m_n \frac{A_\alpha A_D}{A_\alpha + A_D}$ represents the reduced mass of the system with m_n=931.5 MeV giving the mass of a nucleon in energy unit. The Sommerfeld parameter $\eta= \frac{\mu}{\hbar^2}\frac{Z_\alpha Z_D e^2}{k}$, e^2=1.4398 MeV fm. With the radius $R=r_B = r_0(A_\alpha^{1/3} + A_D^{1/3})+2.72$, r_0= 0.97 fm. The quantity $\rho = kR$ is defined.

The expression for logarithm of decay half-life $T_{1/2}$ derived by us in [2] is given below.

$$\log T_{1/2} = a\ \chi + c + d + b_\ell, \qquad (1)$$

where $\chi = Z_\alpha Z_D \sqrt{\frac{A_\alpha A_D}{(A_\alpha + A_D)Q_\alpha}}$,

$$a = 1.4398\pi\sqrt{2(931.5)}/197.329,$$
$$d = -2\log D,$$
$$D = \frac{2\times 931.5\times\sqrt{1.4398\times 2\pi}}{(197.329)^2\sqrt{0.693\times 197.329\times 0.333\times 10^{-23}}}.$$

$$\left\{\begin{array}{c} c = -2\log S\ , \\ S = 70\ c_f\ R\ G_\ell\ \left(\frac{A_\alpha A_D\sqrt{Z_\alpha Z_D}}{A_\alpha + A_D}\right), \\ G_\ell = \sum_j^N G_j,\ \ \mathrm{N} > 500, \\ G_0 = 1, \quad G_1 = \frac{\eta\rho}{(\ell+1)}, \\ (n+1)(n+2\ell+2)G_{n+1} = 2\eta\rho G_n - \rho^2 G_{n-1}, \end{array}\right. \qquad (2)$$

$$\left\{\begin{array}{c} b_\ell = \log(q_\ell), \\ q_\ell = \frac{2\eta(2\ell+1)}{P_\ell(\eta)\rho^{2\ell}}, \\ P_\ell(\eta) = \frac{2\eta(1+\eta^2)(4+\eta^2)....(\ell^2+\eta^2)2^{2\ell}}{(2\ell+1)[(2\ell)!]^2}, \end{array}\right. \qquad (3)$$

$$c_f = \left\{\begin{array}{ll} 0.30 & \text{if}\quad \ell = 0, \\ 0.10 & \text{if}\quad \ell > 0. \end{array}\right. \qquad (4)$$

However, to fit the data of an individual case, one can marginally vary the value of the

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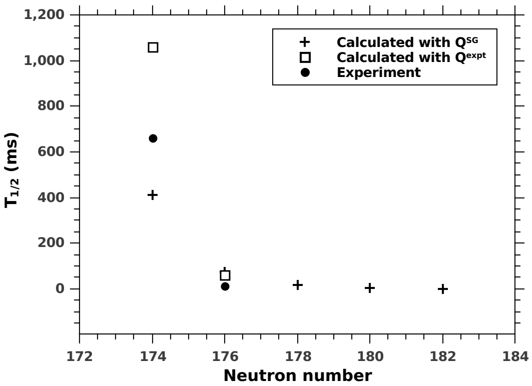

FIG. 1: Plot of the results of decay half-live, $T_{1/2}$ (in milli-seconds (ms)), as a function of neutron number in the decay chain of $^{296}_{118}$Og. Results calculated by formula (1) using Q_α^{expt} are denoted by open squares. The symbol plus denotes results of $T_{1/2}$ calculated through (1) by using Q_α^{SG}. The experimental results are shown by solid circles obtained from [1] for $\ell = 0$ state of alpha-decay.

parameter c_f.

By using the formula (1) we calculate the α - decay half-lives using Q-values derived by us and compare them with the results of half lives calculated using experimental Q-values in the cases of two chains of nuclei listed in Table 1. The results of half lives with our model dependant Q-values are denoted by $T_{1/2}^{calc}(Q_\alpha^{SG})$ and those with experimental Q-values are denoted by $T_{1/2}^{calc}(Q_\alpha^{expt})$. First of all, the results of $T_{1/2}^{calc}(Q_\alpha^{expt})$ with experimental Q-valus are found to be close to the corresponding measured results of half lives denoted by $T_{1/2}^{expt}$ in cases of all nuclei listed in Table 1. The results for the nuclei appearing in the decay chain $^{296}_{118}$Og $\rightarrow$ $^{292}_{116}$Lv $\rightarrow$ $^{288}_{114}$Fl are also shown in figure 1. This close fitting of the data explains the efficacy of the formula (1) for the theoretical estimate of the α-decay half-lives. The calculated results $T_{1/2}^{calc}(Q_\alpha^{SG})$ with our model Q-values are not far away from the experimental results as seen in figure 1 and Table 1. The differences found in the results of $T_{1/2}^{calc}(Q_\alpha^{expt})$ and $T_{1/2}^{calc}(Q_\alpha^{SG})$ are due to the small differences of the order of 300 keV between the results of measured Q-values, Q_α^{expt} and our model dependant Q-values, Q_α^{SG}. Efforts are on to narrow down this difference further by addressing different aspects more carefully while deriving the results of Q_α^{SG} based on Liquid Drop Model.

TABLE I: Calculated α-decay half-lives $T_{1/2}^{calc}$ using experimental Q-value, Q_α^{expt}, and Q-values derived by Sahu and Gambhir, Q_α^{SG} in formula (1) with fixed value of parameter c_f=0.3. The experimental results of Q_α^{expt} and half-lives $T_{1/2}^{expt}$ for ℓ=0 are taken from [1]

Parent	Q_α^{expt} MeV	Q_α^{SG} MeV	$T_{1/2}^{expt}$	$T_{1/2}^{calc}(Q_\alpha^{expt})$	$T_{1/2}^{calc}(Q_\alpha^{SG})$
Chain A					
$^{304}_{122}$X2	-	12.307	-	-	0.96 ms
$^{300}_{120}$X0	-	11.79	-	-	3.65 ms
$^{296}_{118}$Og	-	11.27	-	-	15.45 ms
$^{292}_{116}$Lv	10.78	10.748	13 ms	61 ms	74 ms
$^{288}_{114}$Fl	10.07	10.223	0.66 s	1.06 s	0.41 s
Chain B					
$^{302}_{122}$X2	-	12.36	-	-	0.79 ms
$^{298}_{120}$X0	-	11.84	-	-	2.98 ms
$^{294}_{118}$Og	11.82	11.323	0.69 ms	0.92 ms	12.44 ms
$^{290}_{116}$Lv	11.00	10.801	8.3 ms	18 ms	57 ms
$^{286}_{114}$Fl	10.35	10.276	0.20 s	0.20 s	0.31 s

References

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