Alpha decay studies of even-even nuclei from ground state to ground state transition

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Abstract: The alpha decay half lives for the isotopes of Cm nuclei in the range238≤A≤250 and Cf nuclei in the range 240≤A≤256 have been studied using CYEM model by including deformation effects. The computed half-lives are compared with available data and are found in good agreement. The calculated hindrance factor is found to be closer to unity.

Introduction: Alpha decay is a very important process in nuclear physics which led to most valuable information on nuclear structure and nuclear reaction. Gamow's theory could explain the alpha decay process by means of the wave mechanics. The alpha particles are supposed to be pre-formed within in the nucleus and emitted by tunnelling through the barrier. Aim of the work is to study the half-lives of alpha- decay for the isotopes of Cf and Cm nuclei using CYEM model [1] by including deformation effects. The calculated half-lives are compared with experimental data and other model and are found to be good agreement with each other

Cubic plus Yukawa plus Exponential Model: It has a cubic potential for the overlapping region which is smoothly connected by a Coulomb and Yukawa plus Exponential potential for the region after separation. If the Q-value of the reaction is taken as the origin, the potential for the post - scission region as the function of the centre of mass distance 'r' of the fragment is given by

$$V(r) = V_c(r) + V_n(r) + V_l(r) - V_{df}(r) - Q_\alpha \qquad (1)$$

Here V_c is the coulomb potential between a spheroidal daughter nucleus and spherical emitted alpha particle, V_n is the nuclear interaction energy due to finite range effects of Krappe et al; and V_{df} is the change in nuclear interaction energy due to quadruple deformation of the daughter nucleus, $V_l(r)$ is the centrifugal potential term. The angular momentum carried by the alpha particle in a ground state to ground state transition of even-even nucleus is zero (hence$V_l(r)$)=0 in equation1). In odd-even or odd-odd nuclei, it could not be equal to zero. The values of natural angular momentum have been obtained from the usual nuclear spin and parity conservation laws. The energy of alpha particle emitted from nucleus in alpha decay is

$$Q_\alpha = \Delta M_P - (\Delta M_D + \Delta M_\alpha) + [\, k_1(Z_P^{\beta 1} - Z_D^{\beta 1}) - K_2 Z_C^{\beta 2}] \qquad (2)$$

Where Mp, M_D, M_α are the mass excess of parent, daughter and alpha nuclei as tabulated by Audi et al [2].Where the terms in the brackets represent the effect of the screening to the nucleus caused by the surrounding electrons. The quantity $K Z^\beta$ represents the total binding energy of the Z-electrons in the atom, where the values $k_1=8.7\times10^{-6}$ M e V and β_1 = 2.517 for nuclei of Z ≥ 60 and k_2=13.6 x10^{-6} Me V and β_2=2.408 for Z < 60 have been found from reported by Huang et al[3].

Expressing the energies in MeV, lengths in fm and time in seconds for calculating the life time of the decay system we use the formula,

$$T = \frac{1.433\times10^{-21}}{E_v}\,(1+\exp(k)) \qquad (3)$$

Results and discussion: We have calculated alpha decay half lives for experimentally known even-even nuclei of Cf and Cm isotopes by including quadruple and hexadecapole deformations of parent and daughter but treating the alpha particle as spherical one. The deformation parameter values are taken from Ref [4]. The calculated half life values are found to be in good agreement with available data. The standard deviation is estimated using the following expression.

$$\sigma = \sqrt{\frac{1}{(n-1)}\sum_{i=1}^{n}[\log T_i^{\text{theor.}} - \log T_i^{\text{exp.}}]^2}$$

The estimated standard deviation for the half lives by our model is 0.5659 while the same calculated by Ref [5] is 0.56401. The hindrance Factor (HF) is calculated by the formula, HF= $\frac{T_{1/2}^{exp.}}{T_{1/2}^{thero.}}$. The calculated HF is close to unity which shows better result.

Table1.Logarithmic half lives for alpha decay of even-even nuclei from ground state to ground state transition.

Decay mode	Q (Me V)	Log T (s)			HF
		CYEM	Expt.	Ref[5]	Cal.
Cm^{238}→Pu^{234}	6.658	5.49	≥4.93	5.26	0.2754
Cm^{240}→Pu^{236}	6.438	6.47	6.52	6.29	1.122
Cm^{242}→Pu^{238}	6.258	7.35	7.28	6.86	0.8511
Cm^{244}→Pu^{240}	5.948	8.93	8.88	8.57	0.8913
Cm^{246}→Pu^{242}	5.518	11.44	11.26	11.10	0.6607
Cm^{248}→Pu^{244}	5.208	13.46	13.15	13.14	0.4898
Cm^{250}→Pu^{246}	5.208	13.53	12.45	13.48	0.0832

Fig.1.Logarithmic half lives of alpha decay Vs Q values including deformation effects.

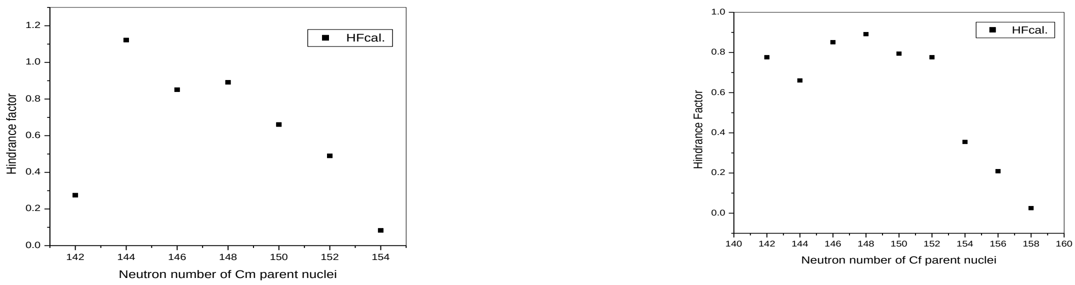

Fig.2.The calculated Hindrance Factor of $Cm^{238-250}$ and $Cf^{240-256}$ nuclei.

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