Role of nuclear surface tension coefficient in alpha decay process of the superheavy nuclei

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Introduction

The present paper "role of nuclear surface tension in alpha decay" resulted from the need to improve the Isospin Cluster Model [1], where the excess of neutron and proton numbers are taken in account effectively of a nucleus in decay calculations. The appropriate value of nuclear surface tension coefficient in proximity potential [2] which plays an important role to estimate the nuclear attraction between two nuclear surfaces is reviewed, in this model. The Nuclear proximity force is proportional to the surface tension and its contribution necessarily should be appropriate [3].

The synthesis of super heavy elements, formed by either of cold fusion or hot fusion process, is primarily decay through alpha-particle emission. The successive emission of alpha particles from a superheavy element ends at spontaneous fission [1,2].

Recently, the Isospin Cluster Model (ICM) is used successfully to calculate the alpha decay half lives, which is an advance version of the Preformed Cluster Model (PCM) [4].

Isospin Cluster Model

The Isospin Cluster Model is an extension of the Preformed Cluster Model (PCM) [4] uses the dynamical collective coordinates of mass and charge asymmetries η and η_z on the basis of Quantum Mechanical Fragmentation Theory. The decay constant λ in PCM is defined as

$$\lambda = \frac{\ln 2}{T_{1/2}} = P_0 \nu_0 P \qquad (1)$$

Here P_0 is the cluster preformation probability and P is the barrier penetrability which refer, respectively, to the η - and R- motions. ν_0 is the barrier assault frequency. P_0 are the solutions of the stationary Schrodinger equation in η ,

$$\left\{-\frac{\hbar^2}{2\sqrt{B_{\eta\eta}}}\frac{\partial}{\partial\eta}\frac{1}{\sqrt{B_{\eta\eta}}}\frac{\partial}{\partial\eta}+V_R(\eta)\right\}\psi^{(\nu)}(\eta)=E^{(\nu)}\psi^{(\nu)}(\eta) \qquad (2)$$

Which on proper normalization are given as

$$P_0 = \sqrt{B_{\eta\eta}}\left|\psi^{(0)}(\eta(A_i))\right|^2 \left(2/A\right) \qquad (3)$$

The WKB tunneling probability calculated is $P= P_i P_b$ with

$$P_i = \exp\left[-\frac{2}{\hbar}\int_{R_a}^{R_i}\{2\mu[V(R)-V(R_i)]\}^{1/2}dR\right] \qquad (4)$$

$$P_b = \exp\left[-\frac{2}{\hbar}\int_{R_i}^{R_b}\{2\mu[V(R)-Q]\}^{1/2}dR\right] \qquad (5)$$

The nuclear charge radius is given by the Eqn. given below;

$$R_{00i} = \sqrt{\frac{5}{3}}\left\langle r^2\right\rangle^{1/2}$$

$$=1.240A_i^{\frac{1}{3}}\left\{1+\frac{1.646}{A_i}-0.191\times\left(\frac{A_i-2Z_i}{A_i}\right)\right\}fm$$

$$(i=1,2)$$

The fragmentation potential ($V_R(\eta)$ in eq (2) is calculated simply as the sum of Coulomb interaction, the nuclear proximity potential V_p and the ground state binding energies of two nuclei:

$$V(R_a,\eta) = -\sum_{i=1}^{2}B(A_i,Z_i)+\frac{Z_1Z_2e^2}{R_a}+V_P \qquad (6)$$

The proximity potential between two nuclei is defined as

$$V_p = 4\pi\bar{C}\gamma b\phi(\xi) \qquad (7)$$

Where γ is the specific nuclear surface tension and defined as

$$\gamma=\gamma_0\left[1-k_s\left(\frac{N-Z}{A}\right)^2\right]MeV\ fm^{-2} \qquad (8)$$

The values of γ_0 *and* k_s are used from ref [5-8].

Calculation and Results

In the present paper various values of nuclear surface tension are taken from the ref [5-8] to see the effect of its on the proximity force between two nuclear surfaces and hence a result for alpha decay half-lives analyzed within the improved Isospin Cluster Model.

Table 1: The decay half-lives using various set of values of γ_0 *and* k_s in γ for the super heavy element $^{299}120$.

Parent	**Half-life $T_{1/2}$ (sec)**				
^{299}120	**Q-Value (MeV)**	**Ref [5]**	**Ref [6]**	**Ref [7]**	**Ref [8]**
Ref [9]	13.106	1.46E-02	9.04E-02	8.20E-03	5.70E-03
Ref [10]	13.06	1.67E-02	1.00E-01	9.41E-03	6.58E-03
Ref [11]	13.33	7.96E-03	5.54E-02	4.26E-03	2.87E-03
Ref [12]	13.23	1.04E-02	6.87E-02	5.69E-03	3.89E-03

The alpha decay calculation made here for the superheavy element 299120, which is not yet observed. The Z=120 nuclei are planned to be synthesized in the nuclear reaction 54Cr + 248Cm (A=302, Z=120) where 3-neutrons emission from the compound nucleus $^{302}120$ is expected. In summary, it is observed that calculated half-lives are extremely sensitive to the Q values and a small change affects the results significantly also role of the nuclear surface tension coefficient appears in theTabe1. The right choice of surface tension for the alpha decay calculations in superheavy element is subject of interest.

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