Theoretical investigation on 2α- Decay of ^{209}Bi isotope using CYEM

G.M.Carmel Vigila Bai[1], *M.Thenmozhi[2](Reg. No. 22213112132015), R.Racil Jeya Geetha[2]
1. Department of Physics, Government Arts and Science College, Konam, Nagercoil, Kanyakumari district.
2. Department of Physics, Nesamony Memorial Christian College, Marthandam, Kanyakumari district.
Email: mthenmozhi9696@gmail.com

Introduction:

Double particle emission is a type of radioactivity in the field of Nuclear Physics. Double alpha decay is a rare nuclear decay occurrence in which a radioactive nucleus expels two identical alpha particles simultaneously, in opposite directions. In 1985[1], Poenaru made the inaugural prediction of the Double alpha decay. Various theoretical models have been proposed to study the Double Alpha(2α) Radioactivity.

In our previous paper[2,3], we have presented, the calculated 2α-decay half life of various isotopes using our well known Cubic plus Yukawa plus Exponential Model(CYEM) in two sphere approximation. In our present paper, we have calculated the 2α-decay half life of ^{209}Bi isotope using our CYE Model and the resultant values are compared with available theoretical models and also compared with first experimental limit of ^{209}Bi reported by V. I. Tretyak[4].

Cubic plus Yukawa plus Exponential Model (CYEM):

In order to study the Double Alpha Decay characteristics of radioactive nuclei, we have used our developed[5] realistic model called Cubic plus Yukawa plus Exponential Model (CYEM), in which we use a cubic potential in the pre-scission region which is connected by a Yukawa plus Exponential potential in the post scission region. The potential as a function of r which is the centre of mass distance of the two fragments for the post scission region is given by,

$$V(r) = \frac{Z_1 Z_2 e^2}{r} + V_n(r) - Q$$

Where, Vn(r) is the nuclear interaction energy and the potential for the pre scission region is

$$V(r) = -E_v + [V(r_t) + \left\{ s_1 \left[\frac{r-r_i}{r_t-r_i}\right]^2 s_2 \left[\frac{r-r_i}{r_t-r_i}\right]^3 \right\}$$

Here the zero-point vibration energy is explicitly included without breaking the law of conservation of energy. For calculating the zero point vibration energy E_v,

$$E_v = \frac{\pi\hbar}{2}\left[\frac{(\frac{2Q}{\mu})^{1/2}}{(C_1+C_2)}\right]$$

Where C_1 and C_2 are the central radii of the fragments and is given by

$$C_i = 1.18\, A_i^{1/3} - 0.48 \qquad i=1,2$$

and μ is reduced mass,

$$\mu = \frac{m_1 m_2}{m_1 + m_2}$$

The half-life time value is calculated by using the formula

$$T = \frac{1.433 \times 10^{-21}(1+\exp K)}{E_v}$$

The action integral K is given by

$$K = K_L + K_R$$

Table-1: Double Alpha Decay half-life of ^{209}Bi isotope

Parent	Q (MeV) [4]	Method	$T_{1/2}$ (years)	Ref.
^{209}Bi	3.292	Experimental limit	$>2.9\times10^{20}$	[4]
		Semi empirical formula	4.266×10^{113}	[4]
		CPPM	1.380×10^{119}	[7]
		MGLDM	6.166×10^{113}	[7]
		MGDM & Q	1.905×10^{111}	[7]
		MLDM &Ac	1.230×10^{115}	[7]
		MGLDM & Z_c, Z_d	2.951×10^{115}	[7]
		MGLDM & C	1.122×10^{109}	[7]
		MGLDM & I	1.820×10^{115}	[7]
		SemFIS formula	6.026×10^{22}	[7]
		Denisov's Model	9.772×10^{49}	[8]
		CYEM	6.310×10^{117}	**[*]**

[* present work]

Result and discussion:

Nuclear decay (A,Z) $\longrightarrow$ (A-8, Z-4) with simultaneous emission of two alpha particles is studied using our well known Cubic plus Yukawa plus Exponential Model(CYEM) with two sphere approximation. In this paper, 2α-decay half life of ^{209}Bi isotope is calculated and is compared with available theoretical models.

In 2021, V.I.Tretyak reported, the first experimental limit for double alpha decay of ^{209}Bi as $T_{1/2} > 2.9 \times 10^{20}$ years at 90% Confidence Level using the data from ref[6]. In the table we have presented, the half life time of ^{209}Bi isotope of our Model and is compared with Semi empirical formula of V.I.Tretyak, and Coulomb Proximity Potential Model (CPPM), Modified Generalized Liquid Drop Model(MGLDM), and MGLD Model with a different dependent preformation factors (i.e., Q-value(Q), Size of emitted cluster (A_c), Atomic number of cluster and daughter(Z_C,Z_d), Combination of Q, A_c, Z_c & Z_d, and Isospin parameter(I)) of K.P.Santhosh. Our resultant calculated half life time values are well agreement with the values of other available theoretical models.

References:

[1]. D.N.Poenaru and M.Ivascu, J.Physique Lett.46,L-591-L-594,(1985).

[2]. G.M.Carmel Vigila Bai, M.Thenmozhi, Proceedings of ICIRC ISBN:978-93-5812-971-7, (2023).

[3]. G.M.Carmel Vigila Bai, M.Thenmozhi, Proceedings of NCAFM (2023).

[4]. V.I.Tretyak, Nucl.Phys.At.energy 22,121 February (2021).

[5]. G.Shanmugam, G.M.Carmel Vigila Bai and B. Kamalaharan, Phys. Rev. C51, 2616 (1995).

[6]. P.de Marcillac et.al., Nature 422, 876 (2003).

[7].K.P.Santhosh and Tinu Ann Jose, PHYSICAL REVIEW C 104, 064604 (2021).

[8].V.Yu. Denisov, Physics Letters B 835, 137569, (2022).