Spontaneous emission of two-alpha particles from various nuclei

G.M.Carmel Vigila Bai[1], *M.Thenmozhi[2], 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.
[1,2]Affliated to Manonmaniam Sundaranar University, Abhishekapatti, Tirunelveli-12.
Tamil nadu, India.

Introduction:

Simultaneous emission of two identical alpha particles from parent nuclei is known as double alpha radioactivity. Initially double alpha decay was discussed by V.Yu.Novikov in 1979[1] and the author calculated 2α decay half-life of some isotopes and presented in Ref.[2]. Then in 1985, D.N.Poenaru et.al. predicted half-life of (^{219,220}Ac,^{220,221}Th,^{222}Pa) isotopes via double alpha decay using ASAFM[3]. Followed by this several theoretical models are suggested to study the spontaneous double alpha decay[4-9].

In our previous works[10,11], we have studied the 2α-decay properties of some isotopes by employing our Cubic plus Yukawa plus Exponential Model(CYEM) in two sphere approximation and is compared with available other theoretical models. In this article, we have calculated the double alpha decay of ^{148}Sm,^{152}Gd, ^{156}Dy,^{190}Pt,^{219,220}Ac,$^{220.221}$Th,^{222}Pa,^{234}U isotopes using our well known CYE Model with and without deformation factors, and the resultant half-life values are compared with the other theoretical models.

DESCRIPTION OF OUR MODEL:

In order to study the Double Alpha Decay characteristics of radioactive nuclei, we have used our developed[12] 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,

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

Here Vn(r) is the nuclear interaction energy, V_{df} is change in nuclear interaction energy due to the quadrupole and hexadecapole deformation of the parent and daughter nuclei. If the nuclei have spheroidal shape, the radius vector R(θ) making an angle θ with the axis of symmetry locating sharp surface of a deformed nuclei is given by[13],

$$R(\theta) = R_0\left[1 + \sum_{n=0}^{\infty}\sum_{m=-n}^{n}\beta_{nm}Y_{nm}(\theta)\right]$$

HALF LIFE TIME:

Half life time of the radioactive isotopes are calculated by the formula,

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

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 is

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

Where μ is reduced mass of the nuclei and C_1 and C_2 are the central radii of the fragments and are given by

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

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

The action integral K is given by
$K = K_L + K_R$

*Electronic address: mthenmozhi9696@gmail.com

RESULTS AND DISCUSSION:

Nuclear decay ${}^{A}_{Z}X \longrightarrow {}^{A-8}_{Z-4}Y + 2\alpha$, is studied in this work using our well known CYE Model in two sphere approximation and also including deformation effects for both parent and daughter nuclei and keeping the emitted fragment as spherical. Decay energy is an important factor to calculate the half life time of a nucleus during the process of nuclear decay. In table-1, we have presented the calculated 2α decay half lives of ^{148}Sm,^{152}Gd,^{156}Dy,^{190}Pt,^{234}U isotopes using our CYE Model with and without inclusion of deformation parameters. In table-2, we have provided the calculated the double alpha half-lives of ^{219,220}Ac,${}^{220.221}$Th,^{222}Pa isotopes using our Model with the inclusion of deformation values for parent and daughter nuclei. The resultant values are compared with available other theoretical models. From the tables, it is seen that the half life values are in good agreement with each other. Beyond that, when the deformation is taken into account, the half-life of an atomic nuclei diminishes. We hope that our current predictions would help the researchers for future research in this domain.

TABLE-1: Calculated half lives of ^{219,220}Ac,^{220,221}Th,^{222}Pa isotopes using our CYE Model with and without including deformation effects.

Model	Parent nuclei	$Q_{2\alpha}$ (MeV)	LogT$_{1/2}$ (years)		
			CYEM [WOD]	CYEM [Present work] [WP&D]	ASAFM [3]
ASAFM	^{219}Ac	18.4	2.29	0.919	2.1012
	^{220}Ac	17.5	4.63	2.895	4.1012
	^{220}Th	18.5	2.77	1.291	2.5011
	^{221}Th	17.8	4.57	2.939	4.1012
	^{222}Pa	18.1	4.52	2.802	4.1012

TABLE-2: Calculated half lives of ^{148}Sm,^{152}Gd, ^{156}Dy,^{190}Pt, ^{234}U isotopes using our CYE Model with and without deformation effects.

Model	Parent nuclei	$Q_{2\alpha}$ (MeV)	LogT$_{1/2}$ (years)		
			Present work		REF[2]
			CYEM [WOD]	CYEM [WP&D]	
REF[2]	^{148}Sm	3.8	61.84	56.77	57.0
	^{152}Gd	4.1	60.36	58.29	57.0
	^{156}Dy	4.44	58.46	54.10	55.0
	^{190}Pt	5.93	57.43	52.12	53.0
	^{234}U	9.45	42.57	36.76	37.0

REFERENCES:

[1]. Yu.N.Novikov, Int. Workshop on U-400 Program. JINR (1979) p.15.

[2].E.E. Berlovich, Yu.N. Novikov, 1986. In:B.S. Dzhelepov (ed.),(Leningrad,1988) p. 107.

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

[4]. F.Mercier, Phys.Rev.Letters, 127, 012501(2021).

[5]. V.I.Tretyak, Nucl.Phys.At.Energy, vol.22,issue 2.pp.121-126(2021).

[6]. K.P.Santhosh, Tinu Ann Jose, Physical Review C 104, 064604(2021).

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

[8]. Deepika pathak et.al. Eur.Phys.J.Plus(2022)137:1115.

[9]. Sreelakshmi et.al. Prceedings of DAE Symp. on Nucl.Phys.67 (2023).

[10]. G.M.Carmel Vigila Bai, M. Thenmozhi, Proceedings of ICIRC(2023).

[11].G.M.Carmel Vigila Bai, M. Thenmozhi, DAE Symp. on Nucl.Phys.67 p. .691-692(2023).

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

[13].H.J.Krappe,J.R.Nix,A. J.Sierk, Phys. Rev. C20, 992(1979).

ACKNOWLEDGEMENT:

The corresponding author's registration number is 22213112132015.