Cluster Radioactivity Study of Pt Isotopes

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Introduction

The cluster radioactivity is a spontaneous emission of clusters of nucleons whose mass is heavier than alpha particles and lighter than the lightest fission fragments. It was first observed by Sandulescu et al. in 1980 [1]. After few years, Rose and Jones first time experimentally observed the cluster decay ^{14}C from ^{223}Ra in 1984 [2]. Till now so many cluster decay has been verified with the emission of ^{14}C, $^{18,20}O$, ^{23}F, $^{22,24\text{-}26}Ne$, $^{28\text{-}30}Mg$ from heavy mass nuclei. So many theoretical models has been proposed to examine the cluster radioactivity [3,4,5] leading to the stable daughter nuclei around ^{208}Pb.

The cluster decay of platinum element is not yet calculated experimentally. However, the authors of [6,7] give some productive information about the decay modes of Pt isotopes. Here we re-examine the decay modes of Pt isotopes within an axially deformed relativistic mean field (RMF) theory with NL3 force parameter set. The Q-value is obtained from the binding energies of the nuclei. With this same Q-value we study the α-decay as well as cluster decay half-life of Pt isotopes using the Viola-Seaborg [8] and Universal formula of Poenaru [9] et al.

Theoretical Formalism

The relativistic Lagrangian density for a nucleon-meson system is [10,11],

$$L = \overline{\psi_i}(i\gamma^\mu \partial_\mu - M)\psi_i + \frac{1}{2}\partial_\mu \sigma \partial^\mu \sigma + \frac{1}{2}m_\sigma^2\sigma^2 - g_\sigma \overline{\psi_i}\sigma\psi_i - \frac{1}{4}\Omega_{\mu\nu}\Omega^{\mu\nu} + \frac{1}{2}m_\omega^2 \vartheta_\mu \vartheta^\mu - g_\omega \overline{\psi_i}\gamma^\mu\psi_i\vartheta_\mu - \frac{1}{4}\vec{B}_{\mu\nu}\vec{B}^{\mu\nu} + \frac{1}{2}m_\rho^2 \vec{R}_\mu \vec{R}^\mu - g_\rho \overline{\psi_i}\gamma^\mu \vec{\tau}\overline{\psi_i}.\vec{R}^\mu \quad \text{……. (1)}$$

All the terms have their usual meaning. The Q-value is calculated from the binding energies of parent nuclei, daughter nuclei and emitted nuclei as;

$$Q = M(A,Z) - M(A_1,Z_1) - M(A_2,Z_2) \quad \text{…….(2)}$$

Where $M(A,Z), M(A_1,Z_1), M(A_2,Z_2)$ are the atomic masses of parent, daughter and emitted nuclei respectively. The possibility to have a cluster decay method is that the decay energy of the Q-value should be greater than zero.

The expression for the ∝-decay half life of Viola-Seaborg is given by,

$$log_{10} T_\alpha = \frac{aZ-b}{\sqrt{Q_\alpha}} - (cZ+d) + h_{log} \quad \text{………….(3)}$$

The details are found in Ref. [8].

The Q value and half lives for the emission of various clusters from the $Pt^{166-172}$ parent nucleus are tabulated in Tablle I. The half life calculations are also calculated by using Universal formula [9] for the cluster decay is given as,

$$log_{10}T_{1/2}(s) = -log_{10}P - log_{10}S + [log_{10}(ln2) - log_{10}\upsilon] \quad \text{……………(4)}$$

Where ν is a constant and S is the preformation probability of the cluster at the nuclear surface which depends only on the mass number of the emitted cluster.

Conclusion

In conclusion, the alpha decay, ^8Be, ^{12}C, ^{16}O, ^{20}Ne, ^{24}Mg decay half lives are calculated from neutron-rich platinum isotopes by using RMF formalism. The calculated half-lives of alpha and other characteristics pertaining to possible cluster emissions with the Q-values obtained from RMF model have been computed and tabulated. The present study of the exotic decays of Pt isotopes may be helpful for future experiments.

Table – I : Cluster decay half-lives of Pt isotopes

Parent Nuclei	Binding Energy	Daughter Nuclei	Binding Energy	Emitted Cluster	Binding Energy	Q-Value (MeV)	T1/2 (V-S)	T1/2 (Univ.)	Expt.
^{166}Pt	1289.133	^{162}Os	1267.051	^{4}He	28.14	6.058	-0.483	0.863	
^{166}Pt		^{158}W	1244.429	^{8}Be	51.507	6.803		55.23	
^{166}Pt		^{154}Hf	1221.997	^{12}C	90.604	23.468		21.652	
^{166}Pt		^{150}Yb	1197.044	^{16}O	129.223	37.134		20.089	
		^{146}Er	1171.203	^{20}Ne	156.243	38.313		42.063	
		^{142}Dy	1145.168	^{24}Mg	194.565	50.6		39.885	
^{168}Pt	1310.482	^{164}Os	1288.635	^{4}He	28.14	6.293	-1.410	-0.115	
^{168}Pt		^{160}W	1265.982	^{8}Be	51.507	7.007		-2.467	
^{168}Pt		^{156}Hf	1244.074	^{12}C	90.604	24.196		19.808	
^{168}Pt		^{152}Yb	1219.833	^{16}O	129.223	38.574		17.559	
^{168}Pt		^{148}Er	1194.571	^{20}Ne	156.243	40.332		37.490	
		^{144}Dy	1168.039	^{24}Mg	194.565	52.122		37.006	
^{170}Pt	1330.731	^{166}Os	1309.192	^{4}He	28.14	6.601	-2.550	-1.303	-2.22
^{170}Pt		^{162}W	1286.752	^{8}Be	51.507	7.528		46.599	
^{170}Pt		^{158}Hf	1263.332	^{12}C	90.604	23.205		22.104	
^{170}Pt		^{154}Yb	1239.339	^{16}O	129.223	37.831		18.660	
		^{150}Er	1216.469	^{20}Ne	156.243	41.981		34.006	
		^{146}Dy	1190.306	^{24}Mg	194.565	54.14		33.456	
^{172}Pt	1350.163	^{168}Os	1328.801	^{4}He	28.14	6.778	-3.169	-1.964	-0.96
^{172}Pt		^{164}W	1306.485	^{8}Be	51.507	6.829		52.769	
^{172}Pt		^{160}Hf	1283.130	^{12}C	90.604	23.571		21.100	
^{172}Pt		^{156}Yb	1259.158	^{16}O	129.223	38.218		17.900	
		^{152}Er	1234.665	^{20}Ne	156.243	40.745		36.349	
		^{148}Dy	1211.765	^{20}Ne	194.565	56.167		30.119	

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