# Study of cluster radioactivity in Pt isotopes

C. Ameerali,* P. S. Athira, and A. K. Rhine Kumar
*Department of Physics, Cochin University of Science and Technology, Cochin -682022, Kerala, India*

## Introduction

Even though the nucleus consists of homogeneous distribution of protons and neutrons, nuclear clustering is an important phenomenon in determining the structure of a light nucleus. Cluster radioactivity is the phenomenon of spontaneous emission of particles higher than alpha particles from the parent nucleus. It was first predicted by Sandulescu, Poenaru and Greiner in 1980 [1] and experimentally observed by Rose and Jones in 1984 [2]. Since then, there are many cluster decays including $^{14}$C, $^{18,20}$O, $^{23}$F, $^{22,2426}$Ne, $^{2830}$Mg and $^{32,34}$Si emission have been experimentally observed. Exotic (cluster) decays are mainly observed in nuclei in the mass region $150 < A < 190$. Different theoretical models have been proposed to study exotic decays. In this work, we study the different cluster decay modes of Platinum (Pt) isotopes using the Coulomb and proximity potential model (CPPM) [4]. Also, there are not many experimental results are available on the exotic decays of platinum isotopes.

## Theoretical framework

In Coulomb and proximity potential model (CPPM), the potential is considered as the sum of Coulomb and proximity potential [3, 4]. The Coulomb repulsion between the fragments is modified by the nuclear proximity potential. This is only applicable to separated fragments. In the pre-scission region (*i.e.,* from parent central radius to touching configuration), proximity treatment is inapplicable. For this phase, in order to estimate the deformation energy, we use a simple power-law interpolation between $r = r_c$ ($r_c$ is the center separation at contact, sum of the radii of daughter and emitted nuclei) to $r = r_0$ ($r_0$ corresponds to the radius of the compound system (the parent nucleus)). Only a small part of the potential is affected by the pre-scission region. Major contribution comes from the separated fragments. For separated fragments, from touching configuration onwards the potential is calculated using the canonical proximity potential [3].

The form of the Coulomb and Proximity Potential for separated fragments is given by,

$$V_{CPP} = \frac{Z_1 Z_2 e^2}{4\pi\varepsilon_0 r} + V_p(z) - Q. \qquad (1)$$

Here, the atomic number of the daughter and emitted nuclei is given as $Z_1, Z_2$, $Q$ is the $Q$-value of the reaction, $r$ is the distance between the centers of fragments and $z$ is the separation between the near-surface of the fragments and $V_p$ is the proximity potential given by Blocki *et al.* [3].

$$V_p = 4\pi\gamma b \left\lfloor \frac{C_1 C_2}{C_1 + C_2} \right\rfloor \phi(z/b). \qquad (2)$$

where $\gamma$ is the surface tension coefficient. $C_1, C_2$ are Siissmann central radii. $b$ is the width of nuclear surface, $b \approx 1$. $\phi$ is the universal proximity potential. Form of the potential in the pre-scission region is given by,

$$V_{CPP} = a\,(L - L_0)^{\nu} \qquad (3)$$

where $L$ is the extreme extension of the configuration. $L_0 = 2C$, where $C$ corresponds to the radius of the compound system (parent nucleus). $a$ and $\nu$ are constants [3] .

## Results

We have calculated the half-lives of different modes of cluster decays from Platinum isotopes within the mass range $166 < A < 178$ using the CPPM. The studied cluster decays

*Electronic address: ameeralic95@gmail.com

| Parent Nucleus $Z(A)$ | Emitted Nucleus $Z(A)$ | Daughter Nucleus $Z(A)$ | Q-value (MeV) | $log_{10}(T_{1/2})$ ($T_{1/2}$ in s) | | |
|---|---|---|---|---|---|---|
| | | | | Present Work | ELDM [5] | UDL [6, 7] |
| 78 (166) | 4 (8) | 74 (158) | 13.961 | 15.932 | 14.671 | 15.7037 |
| 78 (167) | 4 (8) | 74 (159) | 13.741 | 16.669 | 15.3769 | 16.4554 |
| 78 (168) | 4 (8) | 74 (160) | 13.377 | 17.905 | 16.5436 | 17.6924 |
| 78 (169) | 4 (8) | 74 (161) | 13.101 | 18.875 | 17.4441 | 18.6461 |
| 78 (170) | 4 (8) | 74 (162) | 12.758 | 20.205 | 18.6874 | 19.9587 |
| 78 (171) | 4 (8) | 74 (163) | 12.496 | 21.179 | 19.6048 | 20.9277 |
| 78 (172) | 4 (8) | 74 (164) | 12.187 | 22.279 | 20.7663 | 22.1513 |
| 78 (166) | 6 (12) | 72 (154) | 27.94 | 13.727 | 12.6327 | 13.4754 |
| 78 (167) | 6 (12) | 72 (155) | 27.558 | 14.502 | 13.3394 | 14.2552 |
| 78 (168) | 6 (12) | 72 (156) | 26.809 | 15.9 | 14.7774 | 15.83 |
| 78 (169) | 6 (12) | 72 (157) | 26.391 | 17.096 | 15.601 | 16.7332 |
| 78 (170) | 6 (12) | 72 (158) | 25.803 | 18.374 | 16.8212 | 18.0665 |
| 78 (171) | 6 (12) | 72 (159) | 25.382 | 19.389 | 17.6921 | 19.0159 |
| 78 (166) | 8 (16) | 70 (150) | 38.645 | 20.561 | 18.2603 | 19.1797 |
| 78 (167) | 8 (16) | 70 (151) | 39.667 | 18.301 | 16.6961 | 17.4582 |
| 78 (168) | 8 (16) | 70 (152) | 40 | 17.581 | 15.7542 | 16.4222 |
| 78 (169) | 8 (16) | 70 (153) | 39.433 | 18.453 | 16.6164 | 17.3873 |

TABLE I: Cluster decay half-lives of Pt isotopes obtained from the present work (CPPM) are compared with the results obtained from effective liquid drop model (ELDM) [5] and universal decay law (UDL) [6, 7].

are all feasible (Q is value positive) and measurable *i.e.,* $T_{1/2} < 10^{30}$ s. The half-lives we obtained from CPPM are in good agreement with the results from the effective liquid drop model (ELDM) [5] and universal decay law (UDL) model [6] [7]. The decay of $^{12}$C from $^{166}$Pt is the most probable decay mode with a lowest logarithmic half-life of 13.727 s. The present study of the exotic decays of Pt isotopes may be helpful for future experiments.

## Acknowledgement

This work is supported by the Department of Science and Technology, India, via the DST-INSPIRE Faculty award.

## References


[1] A Sandulescu, D.N. Poenaru, W. Greiner, Sov. Jour. Part. Nucl. **11**, 528, (1980).

[2] H. J. Rose and G. A. Jones, Nature (London) **307**, 245 (1984).

[3] J. Blocki and W. J. Swiatecki, Ann. Phys. (N.Y.) **132**, 53 (1981).

[4] K. P. Santhosh, C. Nithya, Phys. Rev. C **97**, 064616 (2018).

[5] Deepthy Maria Joseph, Nithu Ashok, and Antony Joseph Eur. Phys. J. A **8**, 54 (2018).

[6] Dongdong Ni, Zhongzhou Ren, Tiekuang Dong, Chang Xu, Phys. Rev. C **78**, 044310 (2008).

[7] C. Qi, F. R. Xu, R. J. Liotta, R. Wyss, Phys. Rev. Lett. **103**, 072501 (2009).