# Mass distribution and spontaneous fission half-lives of Nobelium isotopes using preformed cluster method

Amandeep Kaur,* Gudveen Sawhney, Jyoti, and Manoj K. Sharma
*School of Physics and Materials Science,*
*Thapar Institute of Engineering and Technology, Patiala - 147004, INDIA*

## Introduction

The collective flow of nuclear matter can be described by the nuclear fission process. Basically, the disintegration of nuclear system into two fragments is termed as nuclear fission, which may take place spontaneously for some radioactive nuclei or may be induced by exciting the target nucleus with light or heavy ion beam. The spontaneous fission (SF) carry significant relevance in the production and sustainability of nuclear systems, particularly for the ones near the drip line. When an heavier nucleus decays into two fragments during fission process, a question arises that what kind of mass division is observed (symmetric or asymmetric). The fission fragment mass distribution is one of the investigation tool which assists us to study the relative contribution of light particles/alpha emission, cluster decay and spontaneous fission etc. It has always been of interest to know about the masses and atomic numbers (A and Z) of light and heavy fragments emitted in the fission dynamics. In this work, an attempt has been made to analyze the SF decay of Nobelium isotopes with mass number A=250 to 262. The calculations are made within the formalism of quantum mechanical fragmentation theory (QMFT) [1] based preformed cluster model (PCM) [2], for the choice of spherical fragmentation.

## Preformed cluster model (PCM)

PCM [2] is worked out in terms of the collective coordinates of mass ($\eta_A$) and charge ($\eta_Z$) asymmetries, the relative separation R, the multipole deformations $\beta_{\lambda i}$ ($\lambda$=2,3,4; $i$=1,2) and orientations $\theta_i$, where 1 and 2 stand for heavy and light fragments. In PCM, the decay constant, and hence the decay half-life time, is defined as

$$\lambda = \nu_0 P_0 P, \quad T_{1/2} = \frac{ln2}{\lambda} \qquad (1)$$

where $P_0$ is the preformation probability of decaying fragments and $P$ is barrier penetration probability referring to $\eta$ and $R$-motion, respectively. $\nu_0$ is the impinging frequency with which cluster hits the potential barrier.

The $P_0$ is obtained by solving the Schrödinger equation in $\eta$-coordinate at fixed $R = R_a$, and reads as

$$P_0 = |\psi(\eta(A_i))|^2 \sqrt{B_{\eta\eta}} \frac{2}{A_{CN}} \qquad (2)$$

$B_{\eta\eta}$ represents the smooth hydrodynamical mass parameter. $R_a$ is the first turning point of penetration path, defined as $R_a = C_1 + C_2 + \Delta R = C_t + \Delta R$. $C_i$ (i=1,2) is the Sussman's central radius which is related to effective radius $R_i$, as $C_i = R_i(1 - b^2/R_i^2)$ and $R_i = (1.28A_i^{1/3} - 0.76 + 0.8A_i^{-1/3})$. The neck-length $\Delta$R is the only parameter of the model which is known to assimilate the neck-formation effects.

## Results and Discussions

Figs. 1(a-d) represent the PCM-calculated preformation probability $P_0$ for the decay of $^{250}$No, $^{254}$No, $^{258}$No and $^{262}$No isotopes, respectively. Note that, the PCM is based on collective clusterization approach, therefore $P_0$ gives the relative preformaton probability of the emission products in binary fragmentation process. One can clearly notice from the figure that fission mass distributions are modified with addition of neutrons in the Nobelium nucleus. The fission mass distribution is relatively broad for the lighter isotope ($^{250}$No),

*Electronic address: amanganday@gmail.com

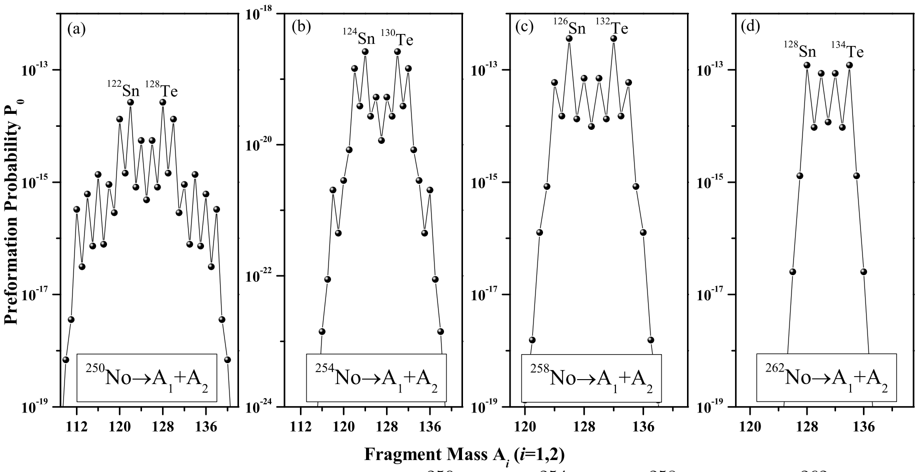


FIG. 1: The $P_0(A_i)$ plotted for the decay of (a) $^{250}$No, (b) $^{254}$No, (c) $^{258}$No and (d) $^{262}$No spontaneous fissioning nuclei, also showing the presence of shell effects around Z=50 and N=82.

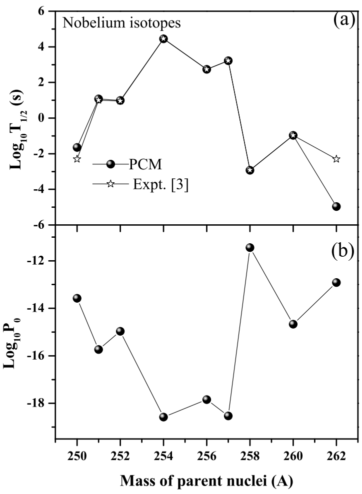


FIG. 2: (a)PCM calculated half-lives compared with experimental data for $^{250-262}$No nuclei.Panel (b) represent the same but for preformation probability $P_0$ calculated in reference to most probable fission fragments for $^{250-262}$No isotopes.

and the contribution of asymmetric fragments reduces as one goes from lighter to heavier parent nuclei. Evidently, the magnitude of $P_0$ for $^{254}$No is smaller than other isotopes, possibly due to its larger half life value (see Fig. 2(a)) Interestingly, the most probable fission fragments (having maximum preformation factor) are found to lie in the neighbourhood of shell closure of charge number (Z=50) and neutron number (N=82), marked in the Fig. 1.

Figs. 2(a) and 2(b) show variation of logarithm of half-lives and preformation probability corresponding to most probable decay fragments, as a function of mass of the parent nuclei. The calculations are performed using the optimized neck-length parameter ($\Delta$R) at angular momentum $\ell$=5$\hbar$, using spherical choice of fragmentation. The magnitude of neck-length is found to vary in the range of -0.64 fm to 1.052 fm. The PCM calculated half-lives show reasonable agreement with the experimental data [3]. Moreover, the trend of half-lives shows almost opposite behaviour to the preformation factor, justifying the fact that $P_0$ imparts useful nuclear structure information in the SF studies of chosen isotopes.

## References


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