# DYNAMICAL MODEL FOR CLUSTER RADIOACTIVITY

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A number of theoretical interpretations are now available for this exotic phenomenon of cluster radioactivity. These are mainly based either on Gamow's theory of α-decay or on nuclear fission. While the calculations using Gamow's theory consider a complete two-step mechanism of first formation and then tunneling through the Coulomb barrier[1], the nuclear fission studies involve only the calculation of tunneling probability through a nuclear interaction barrier[2]. In this paper, we propose a dynamical model based on the quantum mechanical fragmentation process, where mass asymmetry is treated as a dynamical coordinate[3]. A brief report of this work, discussing only the static potential energy surfaces, was published recently[4]. The dynamical model uses a process similar to that used[5] for normal fission.

We assume that after the quantum mechanical tunneling is completed, the system runs down the barrier and satisfies the Schrödinger equation in mass and charge division coordinates $\eta=(A_1-A_2)/(A_1+A_2)$ and $\eta_Z=(Z_1-Z_2)/(Z_1+Z_2)$, respectively, and the relative separation R:

$$\left[-\frac{\hbar^2}{2\sqrt{B_{\eta\eta}}}\frac{\partial}{\partial\eta}\frac{1}{\sqrt{B_{\eta\eta}}}\frac{\partial}{\partial\eta}+V(\eta)\right]\psi^{(\nu)}_{R\eta_Z}(\eta)=E^{(\nu)}_R\;\psi^{(\nu)}_{R\eta_Z}(\eta) \qquad (1)$$

The potential $V(\eta)$ is calculated[4] as the sum of experimental binding energies, the Coulomb interaction and the proximity potential. For the mass parameters $B_{\eta\eta}$, we use the classical model of Kröger and Scheid[6]. Solving (1) numerically, we get, on proper normalizing and scaling, the fractional mass division yields

$$Y(\eta) = |\psi_{R\eta_Z}(\eta)|^2\;\sqrt{B_{\eta\eta}(\eta)}\;\frac{4}{A} \qquad (2)$$

Allowing for the interactions with other degrees of freedom and the contributions from excited ($\nu\neq 0$) vibrational states, we introduce the temperature effects through a Boltzman like function

$$|\psi_{R\eta_Z}|^2=\sum_{\nu=0}^{\infty}|\psi^{(\nu)}_{R\eta_Z}|^2\;\exp(-E^{(\nu)}_R/\theta) \qquad (3)$$

with $\theta=\sqrt{9E/A}$ in MeV. Temperature θ is, however, small that the shell effects still remain important.

Figure 1 (solid lines) shows our calculated mass distribution yields for a rather large θ-value, with the effects of decreasing θ illustrated for $^{223}$Ra. We notice that the yields for the emission of $^{24}$Ne cluster in $^{232}$U and $^{14}$C in each case are very much enhanced. Our calculations also indicate a pre-

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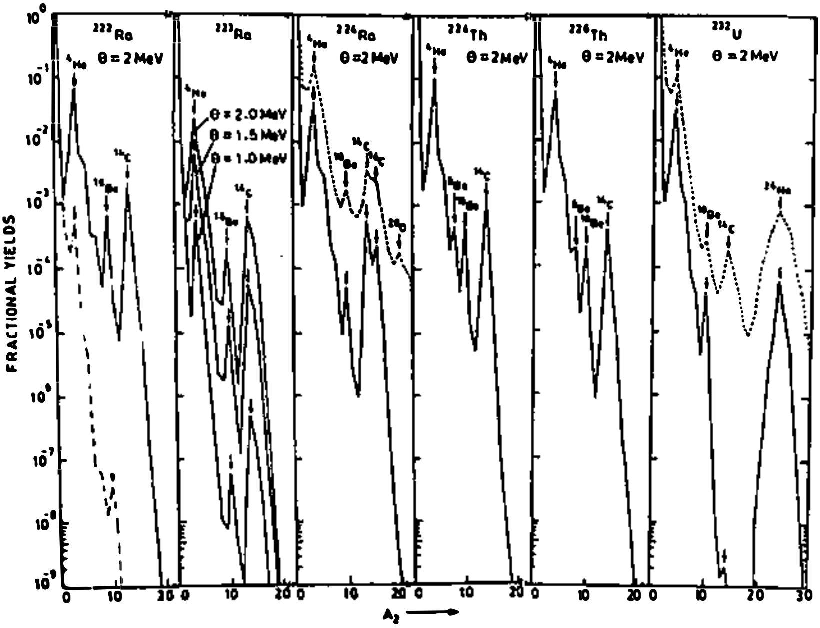


Fig. 1. The calculated mass distribution yields.

ferential emission of $^{10}$Be cluster in each case. At $\theta < 0.5$MeV the yields for $^{14}$C cluster relative to α-particle are predicted to be of the order $<10^{-6}$, which are larger than the measured branching ratios of $\lesssim 10^{-10}$. This discrepancy is perhaps due to our choice of smoothly varying $B_{\eta\eta}(\eta)$, as is demonstrated by calculating the yields for $^{224}$Ra and $^{232}$U (dotted lines) by using constant $B_{\eta\eta}(\eta)$. The yields are then greatly modified. Furthermore, the dot-dashed line in $^{222}$Ra shows that relative yields decrease considerably by neglecting the proximity contribution in the potential.

Concluding, we have shown that the dynamical model, based on quantum mechanical fragmentation process, used earlier for normal fission, also gives the newly observed cluster radioactivity.

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