Entrance channel independence in the decay of $^{47}V^*$ formed in nearly symmetric and asymmetric reactions

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Introduction

Recent studies involving light heavy-ion reactions over a wide range of low bombarding energies E_{lab} < 10 MeV/nucleon, present many interesting features to understand the dynamics of compound nucleus (CN) having A_{CN} ~ 30-60, formed with various target + projectile combinations. The viability of fusion-fission (FF) process and the related reaction dynamics for such light compound nuclei has been a kind of established [1]. According to the simple statistical theory, a CN is formed after complete equilibration of all the degrees of freedom, which subsequently decays into various exit channels. The decay probability for CN is governed by the available phase space and the barrier penetration probabilities are calculated for the respective decay channels. A light mass CN $^{47}V^*$, produced via different reaction channels, is observed to have fully energy damped binary decay process [2], supported by the statistical model calculations based on the transition-state model (TSM).

In the present contribution, the decay of excited CN $^{47}V^*$ formed in nearly symmetric and asymmetric reactions $^{23}Na+^{24}Mg$ (E_{lab}=89.1 MeV) and $^{35}Cl+^{12}C$ (E_{lab}=200 MeV) [2], respectively, with the same excitation energy E_{CN}^*=64.1 MeV, is studied by using the Dynamical Cluster decay Model (DCM) of Gupta and collaborators [3, 4]. The DCM has been applied successfully to the decay of light, medium, heavy and super-heavy mass compound nuclei. $^{47}V^*$offers an ideal example for studying the entrance-channel effects, since it belongs to the well established mass region $40 \leq A_{CN} \leq 80$ of FF phenomenon. It is relevant to mention here that the light compound nuclei $^{28}Al^*$, $^{48}Cr^*$ and $^{56}Ni^*$ decays have been studied extensively by Gupta and collaborators [4] using the DCM, along with entrance channel effects in the decay of $^{48}Cr^*$ [4]. We intend to extend the application of DCM to study the decay of light odd mass CN $^{47}V^*$, for the first time.

Calculations are worked out in terms of neck length parameter ΔR, the only parameter of the DCM. Interestingly, our calculations compared with the experiments show the same good agreement for both the entrance channels, using the same ΔR value, which significantly points out to the entrance channel independence in the decay of $^{47}V^*$, complying with the Bohr's hypothesis [5]. According to the independence hypothesis of Bohr, the excitation process leaves the CN (formed with fixed angular momentum and excitation energy) in a sufficiently complex state that the subsequent decay is statistical and independent of the formation process. However, over here we are interested in a dynamical description of the process, the DCM, based on collective clusterization approach.

Methodology

In DCM, we calculate the CN decay cross-section by using the quantum mechanical fragmentation theory (QMFT), worked out in terms of the decoupled collective coordinates of mass (and charge) asymmetry [$\eta = (A_1-A_2)/(A_1+A_2)$; $\eta_Z = (Z_1-Z_2)/(Z_1+Z_2)$] and R. In terms of these coordinates, using l partial waves, the CN decay cross-section is defined as,

$$\sigma = \frac{\pi}{k^2}\sum_{l=0}^{\ell_{max}}(2l+1)P_0 P\,; \quad k=\sqrt{\frac{2\mu E_{c.m}}{\hbar^2}} \quad (1)$$

where the preformation probability P_0, referring to η motion, is the solution of stationary Schrödinger equation in η coordinate at a fixed R, and P, the WKB penetrability, refers to R motion. Both P_0 and P carry the effects of T and angular momentum l of colliding nuclei at a given $E_{c.m.}$. Here, $\mu = [A_1A_2/(A_1 + A_2)]m$, is the reduced mass, with m as the nucleon mass.

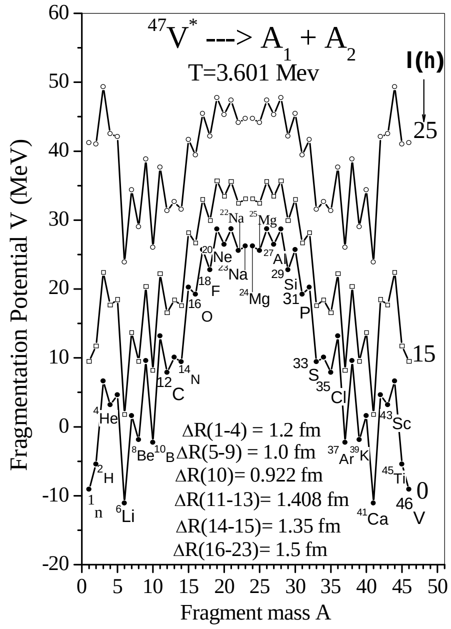

Fig. 1 *The fragmentation potential for the decay of $^{47}V^*$ at temperature T= 3.601 MeV, R= C_t+ΔR, at different l-values.*

Calculations and Discussions

Figure 1 depicts the fragmentation potential V (A_i, i=1, 2) at different *l*-values for fixed T=3.601 MeV. In order to fit the experimental data, we have taken different ΔR-values for different fragment masses. At lower *l*-values LPs ($1 \leq A_2 \leq 4$) are strongly favored over the intermediate mass fragments IMFs ($5 \leq A_2 \leq 23$) but this situation gets reversed at higher *l*-value.

In figures 2 (a) and (b), we have plotted the fusion-fission cross sections of fragments Z_2=5-11 in the decay of $^{47}V^*$ formed in asymmetric $^{35}Cl+^{12}C$ and nearly symmetric $^{23}Na+^{24}Mg$ reactions, respectively, with same excitation energy E_{CN}^*=64.1 MeV, calculated by using the DCM. The calculations are in good agreement with the experimental data [2]. It is relevant to mention here that Z_2 = 6 has larger contribution in comparison to its neighboring fragments, for both the channels. Interestingly, agreement is quite the same for both the entrance channels, with the same choice of ΔR and without fitting it for the channel $^{23}Na+^{24}Mg$. It is very important to point out here that, ΔR seems to work better on the whole, which shows the entrance channel independence for the decay of $^{47}V^*$ formed in asymmetric and near symmetric systems,

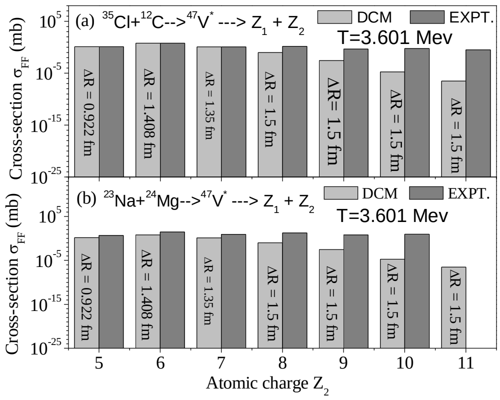

Fig. 2 *(a) The calculated cross-section σ_{FF} (mb) for Z_2=5-11 produced in asymmetric reaction $^{35}Cl+^{12}C$ at T= 3.601 MeV (E_{CN}^* = 64.1 MeV) compared with experimental data. (b) Same as Fig. 2.(a) but for nearly symmetric reaction $^{23}Na+^{24}Mg$, experimental Data for Z_2=11 is not available for this channel.*

hence, confirming/ establishing the Bohr's hypothesis [5]. Further study is under progress.

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