Binary, ternary fission studies of medium, heavy nuclei using dynamical and statistical model

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In this work, the binary decay of excited compound nucleus formed in low energy heavy-ion induced reaction is studied with the use of dynamical cluster-decay model. In which the role of Krappe's T-dependent binding energies instead of Davidson *et al.* formula, the neck-length parameter ($\triangle$R), the factor α, which dictates the mass transfer process, are explicitly studied. Further, on the basis of the statistical theory of fission, for the first time the isotopic distribution of fragments from the binary fission of ^{56}Ni and the complete mass distribution of ternary fission of ^{252}Cf are studied.

The DCM is stems from the preformed cluster decay model, which is based on the quantum mechanical fragmentation theory (QMFT). In DCM, the decay of hot and rotating nucleus has been understood as a collective clusterization process. The light particle (LPs, $A \leq 4$ and $Z \leq 2$) emission and the intermediate mass fragment (IMFs, $A > 4$) emission are treated as the dynamical mass motion of the preformed clusters passing the interaction barrier. Since, the de-excitation of fragments are treated within the cluster decay process, the structural effects enter the model via the preformation probabilities.

In DCM, one of the main ingredients is the temperature (T) dependent binding energies. As a first application, for the calculation of binding energies the role of different T-dependent binding energies due to Davidson *et al.*, Guet *et al.*, and Krappe's forms are studied. Krappe's T-dependent form reproduces the experimental binding energies without any refitting of its coefficients, however the other forms needs to refit its coefficients to achieve a better agreement with the experimental binding energies. Though no refitting of the coefficients is done, the Wigner term in Krappe's form is considered only for nuclei with A >11. The results due to the presence and the absence of a Wigner term in Krappe's form are studied for A <12 nuclei.

The use of Krappe's T-dependent binding energies in DCM is studied [1] for the decay of ^{56}Ni* formed in ^{32}S+^{24}Mg reaction at $E_{c.m.}$ = 51.6 MeV and 60.5 MeV. Though the above reaction is well studied in DCM, we have chosen this reaction is to study the role of Krappe's T-dependent binding energy in DCM. The results obtained using Krappes formula exhibit an explicit preference for α-structured nuclei which is reflected in the fragmentation potential energy, preformation calculations, and in the individual channel cross sections. The observed four nucleon transfer mechanism with the use of Krappe's form is in line with the experimental signature, however, with the use of Davidson's *et al.* form two nucleon transfer mechanism is only observed. The calculated overall cross-section values for the LPs and IMFs compare well with the experimental data. Further, we have calculated the cross sections for each experimentally observed fragment at two incident energies using Krappe's form and is compared with the results obtained from Davidson *et al.* form, and the results of experimental and other theoretical models, such as EHFM and TSM.

The DCM is further reformulated by the inclusion of T-dependent Wigner and pairing energies of Krappe's formula and is applied to study the role of neck length parameter ($\triangle$R), for the decay of ^{56}Ni* formed in ^{32}S+^{24}Mg reaction at $E_{c.m.}$ = 60.5 MeV [2]. In this work, the $\triangle$R value is varied for the individual fragments (from A = 12 to 28) in order to get a better comparison with the experimental data.

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A second order polynomial trend is obtained between mass number of the fragments and △R values for different mass structured fragments such as, 4n, 4n+1, 4n+2 and 4n+3. The LPs emission cross section is also fitted to the measured data by keeping the △R values of fragments $A = 5$ to 28 and tuning the △R value of LPs alone. With the use of fitted △R value of $A = 1$ to 4 and $A = 12$ to 28 and extrapolated △R values of fragments $A = 5$ to 11, our calculated overall cross section values of the LPs emission and the individual fragments ($A = 12$ to 28) emission cross section are found to be in better agreement with the experimental data.

The reformulated dynamical cluster-decay model (DCM) applied to study the decay of odd-A and non-α-structured ^{59}Cu* compound nucleus formed in different entrance channels such as ^{35}Cl+^{24}Mg, ^{19}F+^{40}Ca and ^{32}S+^{27}Al at different incident energies [3, 4]. For the entrance channel ^{35}Cl+^{24}Mg reaction at E_{lab} = 275 MeV, the roles of Wigner and pairing energies in the fragmentation potential are explicitly studied. In addition to this, we have also studied the role of factor α-appearing in the inertia part of the equation of motion dictating the mass-transfer process. The factor α has a significant effect on the structure of preformation probability values and hence in turn we see significant changes in the cross sections. Further, a linear relation is obtained between the free parameter △R and the factor α appearing in the hydrodynamical mass. The △R values for the LPs are more or less constant, but it decreases with increase in α-values for IMFs. For IMFs, a large value of △R requires a smaller value of △R and vice versa. The excitation functions for the production of evaporation residues are calculated for the entrance channel ^{19}F+^{40}Ca reaction, which fits reasonably well with the experimental data. A polynomial relation is obtained from this entrance channel reaction and it is extended for the entrance channel ^{32}S+^{27}Al reaction. A slight modification in the △R values obtained through the polynomial expression of ^{19}F+^{40}Ca reaction resulted in better agreement with the measured data of ^{32}S+^{27}Al.

Within the statistical theory of fission, the isotopic distribution of fragments from the binary fission of ^{56}Ni is studied. From this study, the fragments exhibit the largest yield having the closed shell/sub shell structure in any one of the associated fragments or both of the fission fragments. Further, the ternary mass distribution of ^{252}Cf nuclei for the possible ($A_3 = 16$ to 84) third fragments are studied at two different temperatures $T = 1$ and 2 MeV. The ternary mass distribution shows the ^{94}Se+^{94}Se+^{68}Zn and ^{132}Sn+^{100}Sr+^{20}Ne ternary configurations having the largest yield than the other fragmentations at $T = 1$ and 2 MeV respectively. In addition to this, the ternary fission mass distribution of ^{252}Cf nuclei with A_3 = ^{48}Ca is also studied [5]. From this study, the quantitative results obtained naturally reproduces the experimental expectation of the ternary fragmentation of ^{132}Sn+^{72}Ni+^{48}Ca. Different possible ternary fission modes are also highlighted, such as ^{104}Zr+ ^{100}Sr+^{48}Ca, ^{114}Ru+^{90}Se+^{48}Ca, ^{142}Xe+^{62}Cr+^{48}Ca, ^{152}Ce+^{52}Ca+^{48}Ca and ^{156}Nd+^{48}Ar+^{48}Ca are predicted as the favorable ternary fission modes to look for experiments from the ternary fission of ^{252}Cf nucleus at low excitation energies.

With the use of Talys - 1.4, we have studied the excitation functions of neutron induced reactions of few nuclei and is compared with the available experimental and ENDF data.

References

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