Available online at www.sciencedirect.com
ScienceDirect
Nuclear Physics A 929 (2014) 169–183
NUCLEAR PHYSICS A
www.elsevier.com/locate/nuclphysa

Entrance channel effect with stable and radioactive beams using dynamical cluster decay model

Raj Kumar [a,*], Deepika Jain [b]

[a] *Dipartimento di Fisica "Galileo Galilei" and INFN, University of Padova, Padova-35131, Italy*
[b] *School of Physics and Material Science, Thapar University, Patiala-147004, India*

Received 3 May 2014; received in revised form 25 June 2014; accepted 27 June 2014

Available online 2 July 2014

Abstract

The decay of hot and rotating ^{172}Yb*, formed in two entrance channels ^{124}Sn + ^{48}Ca and ^{132}Sn + ^{40}Ca, is studied using the dynamical cluster-decay model. The effect of entrance channel, deformations (up to β_2), barrier modification and fusion enhancement are addressed. The decay pattern of compound system, formed in different channels at comparable energy around the barrier, shows change in magnitude with structure remains almost same. There is an increase in the fusion probability with decrease in barrier modification, which leads to fusion enhancement at low energies. The higher ℓ values are contributing for ^{132}Sn + ^{40}Ca channel at lower energies as compare to ^{124}Sn + ^{48}Ca. It is inferred that with the use of stable and radioactive beam, forming same compound nucleus, the entrance channel dependence changes with the excitation energy.

Keywords: Entrance channel effect; Dynamical cluster decay model; Radioactive ion beams

1. Introduction

Neutron-rich radioactive ion beams (RIBs) have been used quite extensively in recent past to study the fusion–fission and related processes at low energies. Due to excess neutrons in radioactive nuclei, neutron transfer reactions are supposed to influence the fusion rate significantly, which in turn provides extremely useful information to understand nuclear reaction dynamics

* Corresponding author.
E-mail address: rajkumarfzr@gmail.com (R. Kumar).

http://dx.doi.org/10.1016/j.nuclphysa.2014.06.014

and related phenomena. Fusion reactions involving RIBs are sensitive not only to the entrance channel of interacting heavy ions forming the compound nucleus (CN) but also to the other aspects of the intermediate composite as it equilibrates in energy, mass, angular momentum, and orientation degrees of freedom. The asymmetry of reaction, deformation, orientation and the structure of colliding nuclei significantly affect the reaction dynamics and the corresponding CN formation/decay yield. When a compound system is formed, depending on its mass, it disintegrates by emitting multiple light particles (the evaporation residues, or ER), followed by fission (fusion–fission), and the non-compound quasifission or deep inelastic collision process. Thus, for a compound nucleus reaction, the fusion cross section is defined as the sum of the individual contributions of various processes. The motive of present work that whether the decay of excited compound nucleus depends on the mode of its formation or not in which different entrance channels, leading to same CN, involves stable and radioactive beams. In recent years, fusion hindrance phenomenon [1] has become a hot topic of research in nuclear physics. It is the steep fall of fusion cross sections at energies below the Coulomb barrier in the calculation of one-dimensional barrier penetration model. This phenomenon in heavy-ion reactions close to the Coulomb barrier is reviewed in experiments as well as in theory. An appreciable difference between fusion of heavier and medium-weight nuclei is that fusion cross-section for very heavy system is not enhanced but hindered in frame of coupled channel calculations.

A number of experiments have been performed in the recent past using RIBs to study ER and fusion–fission cross sections, and comparisons were made with reactions involving stable beams [2,3]. Simultaneously, a significant amount of information has been extracted through theoretical calculations as well. Recently ^{172}Yb* compound system was populated by Kolata et al. [4] using stable and radioactive Sn-beams on Ca-targets. Fusion excitation functions were measured at energies above and below the Coulomb barrier for ^{124}Sn + ^{48}Ca and ^{132}Sn + ^{40}Ca reactions. A significant enhancement in ER cross section at below barrier energies is observed for ^{132}Sn + ^{40}Ca reaction. Later Kohley et al. [5] have measured the fusion ER cross-sections for another radioactive ^{134}Te on same ^{40}Ca target.

Theoretically, we have studied the decay of compound systems ^{176,182,188,196}Pt* formed in ^{64}Ni + ^{112,118,124}Sn and ^{132}Sn + ^{64}Ni reactions [6,7] in the framework of dynamical cluster-decay model (DCM) [7–15]. Later entrance channel effect in the decay of ^{190}Pt* was investigated [15] using two different radioactive beams, in ^{126}Sn + ^{64}Ni and ^{132}Sn + ^{58}Ni reactions. However, there was no data at comparable low energies for both the entrance channels. The experimental works of Kolata and Kohley [4,5] offer an opportunity to study the entrance channel effect on the decay of ^{172}Yb* at comparable above as well as below barrier energies. The DCM, which is based on the quantum-mechanical fragmentation theory (QMFT) [16–19], is used for studying the decay of excited hot and rotating compound system with effect of deformation and orientation included. The DCM has been used extensively to address various nuclear structure properties like the role of shell effects, barrier modification, fine structure or substructure of fission fragments, and entrance channel effects for a variety of nuclear reactions during the last few years.

In the present work, our motive is to study the decay pattern of ^{172}Yb* CN using DCM, formed in ^{124}Sn + ^{48}Ca and ^{132}Sn + ^{40}Ca reactions, in reference of entrance channel dependence and fusion enhancement. The fusion excitation function of ^{174}Hf is also studied and fusion enhancement is addressed. It is to be noted here that in DCM, all the energetically favored combinations of mass and charge numbers are to be considered for calculating the fragmentation potential and hence for the preformation probability of any fragment as well. All the fragments are assumed to preborn in the CN with some definite probability. So the deformations of all these