



Cluster decay half-lives using relativistic density dependent double folding model

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Abstract The cluster decay half-lives of heavy nuclei have been calculated within the preformed cluster model by using the microscopic double folding interaction. The densities and the nucleon-nucleon (NN) interactions used are those from relativistic mean field theory. The performance of the relativistic NN interactions with different parametrizations viz. HS, NL2, and NL-SH, together with widely used empirical expressions for the cluster preformation factor are systematically investigated. The NL2 and NL-SH interactions which are especially suitable for describing neutron rich nuclei are found to have better predictive power when combined with an appropriate preformation factor than HS interaction. Predictions of yet to be measured decay half-lives with NL2 interaction together with a proposed empirical expression for the preformation factor are presented. The results are generally seen to compare favourably with the existing theoretical predictions and the available experimental data.

1 Introduction

The discovery of natural radioactivity is generally believed to have marked the beginning of nuclear physics. The spontaneous emission of nuclei such as alpha decay have been exploited to gain excellent insight into the structure and dynamics of the atomic nuclei. The idea of cluster decay, in which the emitted particles are heavier than alpha particle but lighter than fission fragments, was proposed by Sandulescu et al. [1]. The first experimental evidence of such decays [2], has since been followed by other observed cluster decays such as ^{20}O , ^{23}F , $^{22,24,26}\text{Ne}$, $^{28,30}\text{Mg}$, and $^{32,34}\text{Si}$ decay of heavy nuclei [3]. Although cluster decay is understood to have very low probability of occurrence compare to alpha decay, it provides new insight into nuclear structure and

decay phenomena hence the need for further investigation of the decay process.

Many theoretical models have been used to explain the cluster decay phenomenon. These models may broadly be categorised into the preformed cluster model [4–6] where it is assumed that the cluster is pre-born within the parent nucleus, and the super-asymmetric fission model [7–9] in which the parent nucleus is assumed to be deformed continuously as it penetrates the nuclear barrier and the cluster is formed like fission fragment. The former follows from the traditional Gamow approach to alpha decay in which the cluster decay half-lives have been studied using the well known semi-classical WKB framework. In this formalism, the use of proper effective interaction between the cluster-daughter system is crucial to the determination of the observed decay half-lives. In particular, calculated half-lives have been observed to be extremely sensitive to the nuclear potential component of the effective interaction, the choice of which significantly affects the accuracy of the results.

Various phenomenological and microscopic nuclear potentials have been used to study the decay process [10–19]. In the microscopic approach, the nuclear potential is determined by folding cluster and daughter matter densities with the effective Michigan-3-Yukawa (M3Y) nucleon-nucleon (NN) interaction. Many authors have used the double folding interaction to study important nuclear structure properties. In an extension of the potential model, nuclear densities derived from relativistic mean field theory were used together with the M3Y interaction to investigate the systematics of cluster decay preformation probability as well as the properties of superheavy nuclei [20]. A more realistic approach which combines the microscopic NN interaction derived from relativistic mean field theory (RMF), termed as the R3Y interaction, has been shown to equally yield results comparable to those from the well known M3Y interaction [20]. The R3Y interaction has recently been used to describe the

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