Brazilian Journal of Physics (2024) 54:74
https://doi.org/10.1007/s13538-024-01453-7

SOCIEDADE BRASILEIRA DE FÍSICA

Density-Dependent Parametrizations in B3Y-Fetal NN Interaction: Application to Alpha Decay

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Received: 12 December 2023 / Accepted: 5 March 2024
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Abstract
The importance of alpha decay to understanding nuclear structure has been well established. To calculate alpha decay half-lives, the choice of the nuclear potential is important. The Michigan-3-Yukawa (M3Y) nucleon-nucleon (NN) effective interactions and NN effective interactions derived from relativistic mean field theory Lagrangian (R3Y) have been successfully used in alpha decay study within the double-folding model. In this study, we investigate the use of the microscopically deduced B3Y-Fetal effective interactions that stem from the lowest order constrained variational approach (LOCV) in studying alpha decay half-lives. Secondly, we study the effect of using various density-dependent parametrizations on alpha decay half-lives. We found that the density-dependent parametrization BDB3Y0-Fetal gives the best description of the alpha decay half-lives. Moreover, in order to predict the alpha decay half-lives of unmeasured superheavy nuclei with $Z = 120$, an empirical preformation probability formula was obtained using the BDB3Y0-Fetal results and experimental data. The preformation formula obtained together with the Q_α values derived from the Weizsäcker-Skyrme-type nuclear mass model with radial basis corrections (WS-type+RBF) and the BDB3Y0-Fetal NN interaction was used to predict the alpha decay half-lives of unmeasured superheavy nuclei with $Z = 120$.

Keywords Alpha decay · B3Y-Fetal · Double-folding model · Density dependence · Preformation probability

1 Introduction

The importance of alpha decay to understanding nuclear structure has been well established [1–5]. Apart from using empirical formulas, semi-empirical formulas, and phenomenological models, microscopical models have also been employed in the study of alpha decay half-lives. Some of the formulas and models that have been used are Geiger-Nuttal law [6], Viola-Seaborg formula [7], universal decay law [8, 9], scaling law of Brown, scaling law of Horoi [10], Royer formula [11, 12], Ren formula, [13, 14], Akrawy formula [15], cluster formation model [16, 17], preformed cluster model [18, 19], fission-like model [20], effective liquid drop model [21], and generalized liquid drop model [22–24]. Machine learning algorithms have also been used in studying alpha decay [25]. For example, in Ref. [26], the Bayesian neural network was employed to study alpha decay process, and in Ref. [27], four different machine learning models were used to study alpha decay half-lives.

To calculate alpha decay half-lives, one requires the alpha particle preformation probability, penetration probability, and alpha-daughter nuclear interaction potential [28]. The semi-classical WKB approximation has been successfully employed to calculate the penetration probability. The microscopic nuclear potential is often calculated within the double-folding model [4, 29–31]. In this case, the effective NN interactions are folded with the density distributions of both the alpha particle and the daughter nucleus. The Michigan-3-Yukawa (M3Y) NN interactions and NN effective interactions derived from relativistic mean field theory

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Published online: 15 March 2024