Structure and Reaction Aspects of Exotic Nuclei within Effective Interactions

Monalisa Das*
Department of Physics, Siksha 'O' Anusandhan,
Deemed to be University, Bhubaneswar 751030, INDIA

Introduction

Due to the availability of experimental and theoretical analyses as well as the existence of numerous nuclei far from the β-stability line, the 20^{th} century physics has been greatly expanding. Practically speaking, nuclear physics has three facets: investigating the fundamental particles, figuring out how nuclei behave through their interactions, and advancing technology for the benefit of society [1]. The features of nuclei outside the valley of β-stability are currently of great interest. The shell structure of nuclei, which takes the form of magic numbers, is yet another essential component of the nuclear structure. The removal of the traditional magic number(s) and/or the appearance of a new magic number far from the β-stability line are two of the main issues with the nuclear structural physics of typical nuclei, notably the light nuclei. The magic number, although one of nuclear physics's oldest ideas, is essential to understand how finite nuclei are described. Significant progress has recently been made in understanding several nuclear properties at the microscopic level, starting with interacting nucleon and meson fields in a relativistic framework. The development of radioactive ion beams (RIB) has made it possible to investigate the nuclear chart. However, most of the area still needs to be resurveyed. The drip line of the proton-rich side has been considerably better examined than its neutron counterpart. Many unusual phenomena have recently been found, but the ones at the dripline really intrigue us a lot.

Theoretical Formalism

This thesis is aimed to bridge a relationship between the structural and reaction aspects of various isotopic chains. For investigating the structural calculations the Relativistic Mean Field (RMF) model with NL3 and NL3* parameters, created by Green and Miller and later updated by Boguta and Bodmerma, is used and the density-dependent Relativistic Hartree-Fock Bogoliubov (RHB) model with DD-ME2 parametr is taken into consideration. For the pairing computation of the RMF model, the BCS approximation asserts that only pairs of nucleons that are invariant under time-reversal symmetry have a non-zero matrix element in the pairing interaction, making it the most straightforward way for handling pairing correlations. In the case of the RHB model, the Bogoliubov pairing is considered. The Glauber model [2] is also utilised for the investigation of various nuclear cross-sections, such as the elastic scattering cross-section ($d\sigma/d\omega$) and total nuclear reaction cross-section (σ_R). The projectile density and the target density, respectively, are required for the analysis of this model. We calculated several reaction parameters using the nucleonic densities that the relativistic mean-field formalism provided.

Results and Discussions

This thesis examines the structural characteristics of lighter, medium, and higher-mass nuclei with highly asymmetric neutron-to-proton systems. Investigating the nuclei's structural attributes, decay patterns, and reaction characteristics is necessary for a thorough analysis. The synthesis of super-heavy elements close to the beta stability line is now a popular topic in nuclear science because it combines a number of intriguing proper-

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*Electronic address: `dasmonalisa11@gmail.com` ties, including the nuclei's capacity to close their shells, the structure of neutron and proton halo particles, and the nuclei's bubble-like structure. Our study has the major goal of calculating the different shapes and structures of different produced nuclei in both the lower mass zone and the greater mass region. The study of exotic decay processes can lead to a focus on structural analysis and decay modes, as well as the investigation of the reaction properties of exotic nuclei and the exploration of the decay characteristics of highly unstable nuclei on neutron-rich sides. We also estimated the bulk properties of such nuclei for both light, medium, and heavy nuclei [3–5] in order to assess the validity of the model for all types of nuclei. All of our calculated results are then set for comparison with other standard models like finite range droplet model (FRDM), Weizsäcker-Skyrme mass formula (WS3, WS, WS*) parameters and available Expt. data. Medium mass isotopes of Hf within a mass range 170-220 are surveyed and at N = 126, we see a kink and/or drop in the energy of two neutron separations as well as differential variation in the energy of two neutron separations, both of which lead to the signature of shell/sub-shell closure of ^{198}Hfs. The shell gap for N = 126 the also confirmed by the single-particle energy level, which lends support to this [3].

Superheavy elements (SHEs) are defined as elements with proton numbers (Z) that are near the magic number following Z = 82, which corresponds to the element Pb. Studies on the decay modes of super-heavy nuclei are crucial for confirming the existence of newly created isotopes. One of the most important decay modes in the world of super-heavy particles is α-decay. We have examined three decay chains, specifically the 4α-decay chain of the ^{243,245,247}Fm isotope, and have determined the half-lives using distinct formulae which suggest the shell closure and shell stabilised isotopes of these decay chains [4]. Furthermore, a great deal of study is being done to comprehend structure and reaction properties, especially for the isotopes (Z = 35–64) that are present in this area. The halo characteristics develop in a nucleus at the drip line because of the valence particles' very small affinity. On studying the shell closure parameter (D_n (N)) and the energy of the two neutron separations (S_{2n}) indicate that A = 32, 38, and 58 are shell closure nuclei and A = 42, 46, and 52 are weak shell closure nuclei. One projectile and one target are required for reaction research. For the purpose of calculating the reaction cross-section, stable targets like ^{12}C, ^{16}O, ^{40}Ca, ^{90}Zr, ^{124,132}Sn, ^{208}Pb, and ^{304}120 are taken into account and the projectile used is $^{26-48}$Ar. The same targets are used for differential reaction cross-sections in a similar manner, but we focus on ^{32}Ar as the lone projectile. As a result, we draw the conclusion that the scattering angles ($\theta_{c.m}$) and ($d\sigma/d\omega$)) depend significantly on the mass of the target nuclei as well as the projectile's incident energy. This demonstrates how the nuclear structure and nuclear reaction are connected [5].

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