Proton emission from two quasiparticle states in deformed odd-odd nuclei

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Most of the nuclear models agree well with each other while explaining nuclei for which experimental information is known, whereas this agreement is poor while extending to the nuclei yet to be observed in a laboratory. Hence, it is important to study the nuclei far from stability, which can enable us to test and validate the nuclear models and their underlying theories. This thesis work is an attempt in this direction with the study of the properties of extremely proton-rich nuclei.

Most of the models for proton emission explain very well the measured half-lives for spherical as well as deformed nuclei. Simple models are based on semiclassical WKB methods while the deformed proton emitters can be studied more rigorously by identifying that the decay proceeds from the single-particle resonances. Microscopic study of the deformed proton emitters allows us to test the details of the nuclear wavefunction to which the half-lives are quite sensitive. The most consistent theoretical approach in this regard is the nonadiabatic quasiparticle approach which is very successful in bringing out several interesting features of deformed proton emitters including the triaxially deformed ones.

The primary goal of this work is to identify the ground states of odd-odd nuclei in the proton drip line with the aid of decay properties of these nuclei, namely the proton emission half-lives. In case wherever data exists, the rotational spectra are also utilized to extract additional information. Work of this nature has been carried out previously but with the neglect of several correlations including the Coriolis interaction between the quasiparticles and the rotor. Here we present for the first time, a microscopic approach to study proton emission from odd-odd deformed nuclei which includes the pairing, Coriolis and residual *np* interactions [1, 2]. While most of the studies on odd-odd nuclei concern only the energies, a description of decay can test the details of the wavefunctions which could be strongly influenced by the residual *np* interaction.

We undertake the complex task of formulating a proper theoretical framework to study the structure and decay of odd-odd nuclei which is least explored. An exciting feature that can be studied in these nuclei is the interaction between the odd proton and the odd neutron. Though this residual interaction could be weak, in combination with the zero point rotational energy, it leads to several possible combinations of spin for the ground state of the nucleus [3]. These nonadiabatic effects are considered so far in the case of odd-even proton emitters only while in the odd-odd cases these studies were performed [4] within the strong coupling limit. The nonadiabatic approach is characterized by the fact that the Coriolis interaction is considered along with a proper treatment of quasiparticles under the BCS approach [5].

The nuclear mean field is chosen to be of Woods-Saxon type with axial symmetry. For rotation particle coupling in odd-odd nuclei, we present in detail the various matrix elements obtained in the conventional constant/variable moment of inertia approximation. We put forth a new formalism developed in this work, named as the *coupling matrix approach.* The core idea of this formalism is based on the coupled channels approach for odd-even nuclei suggested in the work of Bohr and Mottelson [6]and of Esbensen and Davids [7]. The phenomenon of rotational alignment in odd-odd nuclei has been discussed. The

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TABLE I: Spin and parity assignments for the proton emitters studied in this work. The assignments are based on corroboration with experimental data for the proton emission half-life with the condition that the corresponding state is energetically favoured. Isomeric states are marked with 'm'.

Nucleus	Spin and parity I^π ($\hbar$)	
	Systematics	Present Work
^{112}Cs	0^+, 1^+, 3^+	1^+
^{113}Cs	$3/2^+$	$3/2^+$
^{130}Eu	1^+	1^+
^{170}Au	2^-	2^-
^{170m}Au	9^+	2^+
^{171}Au	$1/2^+$	$1/2^+$
^{171m}Au	$11/2^-$	$11/2^-$

results for the nuclei ^{170,171}Au highlight the importance of the coupling matrix approach when the energy levels of the core deviate from that of a rigid rotor.

The rotational spectrum of ^{180}Ta is discussed first, justifying our approach for the interpretation of rotational bands [8]. Following this, we discuss proton emission from the nuclei ^{130}Eu, ^{112,113}Cs and ^{170,171}Au. Without assuming an exact Nilsson state from where the decay could happen, we could explain the experimentally observed half-lives in all these nuclei. For the considered nuclei, the ground state spin and parity have been confirmed or reassigned with the aid of the measured proton emission half-lives. We discuss the interplay between the Coriolis and the residual *np* interaction as well. We demonstrate that the description of proton emission can test the details of the wavefunctions which may be strongly influenced by the residual *np* interaction.

The results are summarized in Table I, where the spin and parity assigned through our calculations are listed along with the values quoted from the systematics. For assigning spin and parity, we consider the following conditions for the state under consideration:

a) It should be one among the probable lowest lying states,

b) The corresponding proton emission half-lives should be consistent with the measured one, and

c) The above two results should not be sensitive to the strength of the Coriolis coupling.

We conclude that we have successfully developed a full microscopic formalism for proton emission from deformed odd-odd nuclei where nuclear structure and decay aspects are exactly taken into account. This includes the quasiparticle description of Coriolis interaction which is quite important for decay from deformed nuclei and the residual *np* interaction between the odd neutron and the odd proton. The measured proton emission half-lives for all the nuclei considered in this work could be successfully explained by our nonadiabatic quasiparticle calculations even when the core exhibits a non-rotational nature.

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