Ab − initio results of β^- − decay properties of $Z = 8 - 15$ nuclei

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1. Introduction

In the recent past, the β–decay properties of unstable nuclei have been extensively investigated. There are many new experimental data available for the β-decay half-lives of the *sd* shell nuclei. Which give us a good opportunity to perform *ab initio* calculations to compare with the recent experimental data.

More recently our group did several theoretical calculations for beta decay properties using naive shell model and *ab initio* calculations: the nuclear β-decay half-lives for fp and fpg shell nuclei [1]; shell model results of Gamow-Teller (GT) strengths of fp shell nuclei [2] and the study of the GT strengths using *ab initio* interactions in the *sd* shell nuclei for 13 different nuclear transitions [3].

In this work, we have done *ab initio* calculations with in-medium similarity renormalization group (IM-SRG), coupled-cluster effective interaction (CCEI) and chiral effective field theory (CEFT) to calculate the β^-–decay properties of *sd* shell nuclei. We also perform calculation with the phenomenological USDB interaction. This is the first comprehensive study of β^-–decay properties of *sd* shell nuclei using *ab initio* approaches.

2. Formalism

The β–decay partial half-life corresponding to the GT transition from the initial ground state i of the parent nuclei to the final ground state f of the daughter nuclei is given by :

$$f_A t_{i\to f} = \frac{6177}{[(g_A)^2 B(GT; i \to f)]}, \quad (1)$$

where g_A (= -1.260) is the axial-vector coupling constant of the weak interactions, f_A is the axial vector phase space factor that contains the lepton kinematics, and B(GT) is the Gamow-Teller matrix elements.

The total half-life is calculated as

$$\frac{1}{T_{1/2}} = \sum_f \frac{1}{t_{i\to f}}, \quad (2)$$

where f runs over all possible daughter states.

The B(GT) strength is given by

$$B(GT; i \to f) = \frac{1}{2J_i + 1} q^2 |\langle f || \sum_k \sigma^k \tau^k_\pm || i \rangle|^2. \quad (3)$$

Where $|i\rangle$ and $|f\rangle$ are the shell model wave functions for initial and final state, respectively and the $\tau_\pm$ are the isospin operator for the $\beta^\pm$ decay. We use the convention for the β^--decay is $\tau_-|n\rangle = |p\rangle$, J_i is the initial-state angular momentum, and q is the quenching factor.

3. Results and discussion

We did calculations for excitation energies, half-lives, logft, branching fractions and Q-values of *sd* shell nuclei. But, here we are presenting only *ab initio* results of β-decay half-lives for the F isotopes with IM-SRG, CCEI and CEFT in the Fig. 1, more details for other nuclei will be presented during meeting. For the half-lives calculation we use the experimental Q values, which are taken from [4]. In Fig. 1, we have use log frame to plot the half-lives, where the experimental half-lives [5] are connected by solid line and the theoretical half-lives are connected by dashed lines.

The calculated β-decay half-lives from the *ab initio* approaches and USDB interaction for the F isotopes are in a very good agreement with the experimental data. The experimental half-life for ^{20}F → ^{20}Ne decay is

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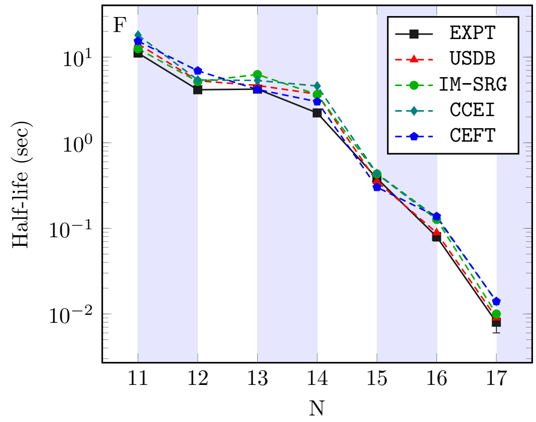

FIG. 1: The β-decay half-life versus the neutron number (N) for the F isotopes.

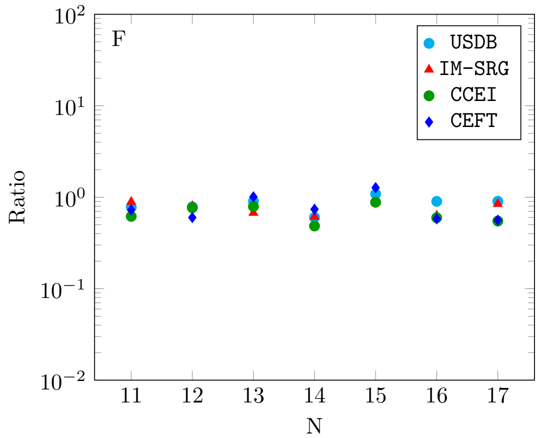

FIG. 2: The ratio of the experimental to theoretical half-lives versus neutron number (N).

11.163±0.0085 s, while the calculated shell-model half-life from the USDB interaction is 14.26 s. They are 12.54 s, 18.07 s and 15.38 s for the IM-SRG, CCEI and CEFT interactions, respectively. The experimental half-life for ^{26}F $\rightarrow$ ^{26}Ne decay is 8.2±2 ms, while the calculated shell-model half-life from the USDB interaction is 9.09 ms. They are 9.71 ms, 14.93 ms and 14.62 ms for the IM-SRG, CCEI and CEFT interactions, respectively.

We also show the ratio between the experimental and theoretical half-lives for the F isotopes in Fig. 2. The ratio are distributed quite close to 1, thus the theoretical results are very close to the experimental data.

4. Summary and conclusions

In the present work we have done first comprehensive study of β^-–decay properties for half-lives, $\log ft$, branching fractions and Q-values of *sd* shell nuclei using *ab initio* approaches: in-medium similarity renormalization group, coupled-cluster effective interaction and chiral effective field theory. For comparison we have also shown results with phenomenological USDB interaction. Overall the half-lives result presented here for F isotopes are showing good agreement with the experimental data.

5. Acknowledgment

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