Physics of isospin

Wojciech Satuła
Faculty of Physics, University of Warsaw, Poland

I shall briefly overview selected aspects of isospin physics in $N \sim Z$ nuclei within a recently developed multi-reference density functional theory (MR-DFT) involving isospin and angular momentum projections and subsequent configuration interaction (CI) calculations [1]. The formalism allows for quantum-mechanically rigorous calculation of isospin impurities to the nuclear wave functions resulting from a rather subtle interplay between the long-range Coulomb force polarizing the entire nucleus and the short-range strong isospin-invariant force. The impurities are prerequisites for the calculation of isospin-symmetry-breaking (ISB) corrections to the superallowed $0^+ \to 0^+$ Fermi beta decays which are used for testing the electroweak sector of the Standard Model (SM) of elementary particles.

The MR-DFT rooted no-core CI approach can be also applied to compute Gamow-Teller (GT) transitions [2]. I will demonstrate, in particular, that our model is able to account for the ground-state GT decays of $T = 1/2$ mirror nuclei in a way that is comparable to the state-of-the-art nuclear shell-model(s). This study addresses the physical mechanism behind a quenching (or renormalization), q, of the axial coupling constant $g_A^{(\mathrm{eff})} = qg_A$ with respect to its free neutron decay value $g_A \approx -1.2701(25)$ linking it to the two-body currents as suggested in Ref. [3]. The mixed Fermi-Gamow-Teller decays of $T = 1/2$ mirror nuclei offer an alternative way for the SM tests provided that, apart of half-lifes, branching ratios, and Q-values, another observable like the neutrino-beta correlation, beta-asymmetry or neutrino-asymmetry is also measured, see Ref. [4,5]. The precision of these experiments is still too low for testing the Standard Model but fast progress in β-decay correlation techniques makes these experiments very promising and keeps the field vibrant see, for example, Ref. [6] for the recent β-asymmetry measurement in ^{37}K decay. Similar to the superallowed $0^+ \to 0^+$ Fermi decays, the analysis of $T = 1/2$ transitions and, in particular, the extraction of V_{ud} depends on theoretical calculation of radiative and many-body ISB corrections to the Fermi branch.

The nuclear DFT is the only consistent effective theory of the ISB forces that can be used over the entire nuclear chart. Indeed, it properly incorporates the long-range behavior of the ISB forces which is due to the Coulomb interaction and can be relatively easily generalized to include the sub-leading strong-force-related ISB effects by adding a local correcting potential [7,8]. In the last part of my talk, I shall present the extended single-reference Skyrme DFT that includes proton-neutron mixing in particle-hole channel and zero-range class II and class III forces breaking, respectively, charge independence (CIB) and charge symmetry (CSB). I shall demonstrate that these extensions allow to account not only for the mirror displacement energies (MDEs) but also for much more subtle effect of the triplet displacement energies (TDEs) which is a measure of the binding-energy curvature within isospin triplet [8,9]. I shall also discuss a connection between our CSB and CIB forces and *ab initio* charge-dependent forces by comparing the coefficients of isobaric mass formula in light nuclei where the *ab initio* results are available [10].

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