Single-particle spectroscopy and resonance strengths in N=Z nuclides*

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The odd-odd $N=Z$ nuclides in the *sd* shell are of particular interest for hydrogen-burning nucleosynthesis, impacting massive stars, novae and x-ray bursts. The proton-capture reactions on these nuclides - ^{18}F, ^{22}Na, ^{26}Al, ^{30}P, ^{34}Cl, and ^{38}K - play an important role in breakout from the hot CNO cycle, affecting reaction flow, the nucleosynthesis end-point, and final abundances, thereby impacting astronomical observables such as elemental and isotopic ratios, and the luminosity of targets of gamma-ray astronomy. Furthermore, many of these nuclides have low-lying spin isomers, requiring explicit treatment in reaction networks of formation and destruction rates of both ground and isomeric states, the latter of which are typically more challenging to constrain experimentally.

For these *sd*-shell nuclides, radiative capture reactions proceed predominantly via isolated proton resonances, the properties of which are crucial for determining the astrophysical reaction rate, and direct measurements of the most important resonance strengths are ultimately desired. However, though progress is being made toward such measurements with recoil separators such as DRAGON, and the newly-constructed separator for Capture Reactions (SECAR) [1] at FRIB, such measurements remain highly challenging, and rely heavily upon previous knowledge of the resonances of interest, derived from indirect techniques. Matters are additionally complicated for nuclides with isomeric states, in which the single-particle overlaps of resonances with both the ground and isomeric states are needed.

However, recent developments in radioactive beams and associated instrumentation are opening multiple opportunities for constraining such reactions, to constrain reaction rates and guide direct measurements. In particular, the for the odd-odd $N=Z$ nuclides above, their self-conjugate nature makes them especially well-suited for indirect studies utilizing mirror symmetry. In this approach, proton-capture cross sections can be deduced from neutron transfer reactions. Furthermore, as these nuclides are within reach of large-basis shell-model calculations with well-constrained effective interactions, such (d,p) data can provide stringent tests of these shell-model calculations, which can subsequently be used to inform astrophysical reaction rates. These odd-odd sd-shell nuclides have been the targets of a subset of the physics program of ORRUBA (the Oak Ridge Rutgers University Barrel Array) and GODDESS - its coupling to the gamma-ray tracking array GRETINA - performed at HRIBF, ATLAS, the NSCL, and FRIB [2]. An overview of these measurements will be presented, including progress in experiments at the ReA Facility at FRIB, utilizing reaccelerated isomeric beams in which the ground/isomeric state beam composition can be adjusted without impact on other beam properties [3,4] - a technique which could eventually be used for direct measurements of capture reactions on isomeric beams with the JENSA gas-jet target [5,6] and SECAR.

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