Isoscalar and isovector spin responses in *sd*-shell nuclei†

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The spin-isospin response and spin-isospin dependent interactions in nuclei are important fundamental problems in nuclear physics and astrophysics. Recently, isoscalar (IS) and isovector (IV) spin M1 transitions have been investigated by high-resolution proton inelastic scattering measurements at $E_p = 295$ MeV.[1)] In this study, the spin magnetic dipole transitions and neutron-proton spin-spin correlations in *sd*-shell even-even nuclei with $N = Z$, ^{20}Ne, ^{24}Mg, ^{28}Si, ^{32}S, and ^{36}Ar along with a *p*-shell nucleus ^{12}C are investigated using shell model wave functions considering the enhanced IS spin-triplet pairing with effective spin operators. In general, the calculated results show good agreement with the experimental energy spectra in $N = Z$ nuclei as far as the excitation energies are concerned. In comparison with the experimental M1 results, the accumulated IS spin strengths up to 16 MeV show small quenching effect, corresponding to the effective quenched operator $f^{IS}(\text{eff}) \sim 0.9$, while a large quenching $f^{IV}(\text{eff}) \sim 0.7$ is extracted for the IV channel. Similar quenching on the IS spin M1 transitions is obtained by the 20% enhanced IS spin-triplet pairing correlations with the bare spin operator. However, the enhanced IS pairing does not change much the excitation energy spectra. The Towner's effective spin operators efficiently reproduce the accumulated experimental IV spin strength, while the quenching of effective operators is much larger than that observed in the IS spin channel. Consequently, an enhanced IS spin-triplet pairing interaction enlarges the proton-neutron spin-spin correlation deduced from the difference between the IS and IV sum rule strengths. The beta-decay rates and the IS magnetic moments of *sd*-shell are also studied in terms of IS pairing and the effective spin operators. Previously, a large quenching of IS magnetic transition strength was suggested in the literature. However, the (p, p') data in Ref. 1) do not exhibit the large quenching effect on the IS spin transitions. This should further be studied experimentally with possible IS probes such as (d, d') reactions with comprehensive theoretical calculations.

References
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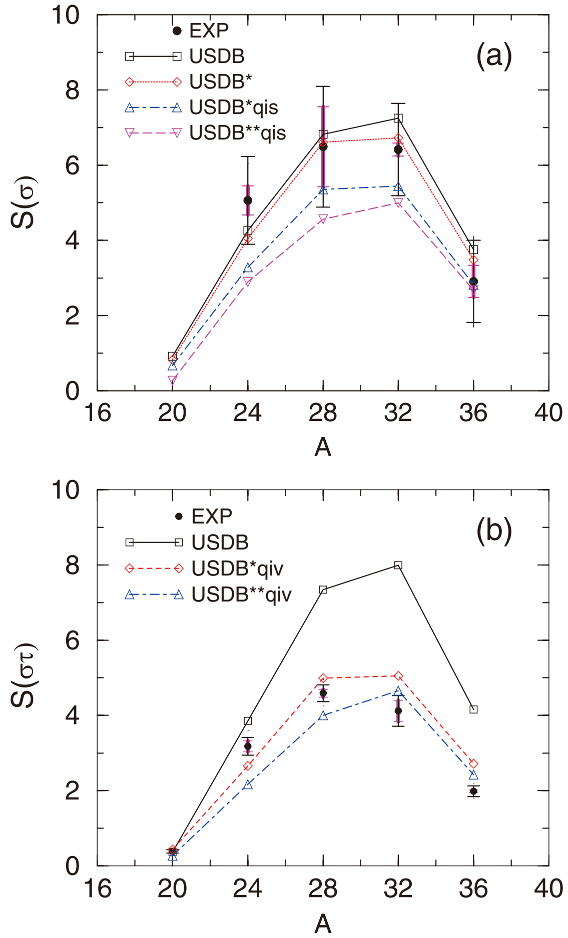

Fig. 1. (Color online) Accumulated spin-M1 transition strengths of (a) IS channel and (b) IV channel. Experimental and theoretical data are summed up to Ex = 16 MeV. Shell model calculations are performed with USDB effective interaction: (a) in the results of USDB* and USDB*qis, the IS spin-triplet pairing interaction is enhanced by multiplying the relevant matrix elements with a factor of 1.1 compared to the original USDB interactions, and the quenching factor f_s^{IS} = 1.0 and 0.9 for IS spin operator, respectively. For USDB**qis, the IS pairing interaction is enhanced by a factor of 1.2 and a quenching factor $f_s^{IS} = 0.9$ is introduced for the IS spin operator. Experimental data are taken from Ref. 1). Long thin error bars indicate total experimental uncertainty, while short thick error bars denote the partial uncertainty from the spin assignment. (b) Effective IV operators[2)] are adopted for spin, orbital and spin-tensor operators for USDB*qiv and USDB**qiv. For the results of USDB*qiv and USDB**qiv, the IS pairing interaction is enhanced by a factor of 1.1 and 1.2, respectively, using the effective operators.