Spectroscopic factors for the N = Z isotope of Si: a theoretical study

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Introduction

Single-nucleon transfer reactions, such as stripping and pick-up reactions, are considered to be important in identifying the single-particle character of states. In the context of the nuclear shell-model for transfer reactions, a comparison between the calculated and observed spectroscopic factors can have significant implications on the occupation probability predictions for the active orbitals and the configuration-mixing present in the state wave functions.

Using two different effective Hamiltonians, Wpn [1] and USDB-cdpn [2] within shell-model, we have calculated the spectroscopic factor strengths, C^2S for some Si isotopes (C and S being the isospin Clebsch-Gordan coefficient and the single-particle spectroscopic factor, respectively). The latter Hamiltonian is charge-dependent. The selected configuration space, *sdpn* has the $1d_{5/2}$, $2s_{1/2}$, and $1d_{3/2}$ valence orbitals for both proton and neutron. In this manuscript, the study regarding a number of positive-parity states of the mid-shell nucleus, ^{28}Si is reported.

Results and Discussion

The previously investigated one-proton stripping reactions that were utilized to extract the spectroscopic factors for ^{28}Si include ^{27}Al(^{3}He, d)^{28}Si [3,4] and ^{27}Al(d, n)^{28}Si [5]. The experimental results and the predictions for the positive-parity states' excitation energies are compared in Fig. 1. For the last two states of $3\hbar$ spin, the USDB-cdpn Hamiltonian provides much better energy values, while the highest $0\hbar$ state (T = 1) gets a quite better prediction from Wpn. In Table 1, (l_p,j_p) = (0,1/2) means the proton $2s_{1/2}$ orbital.

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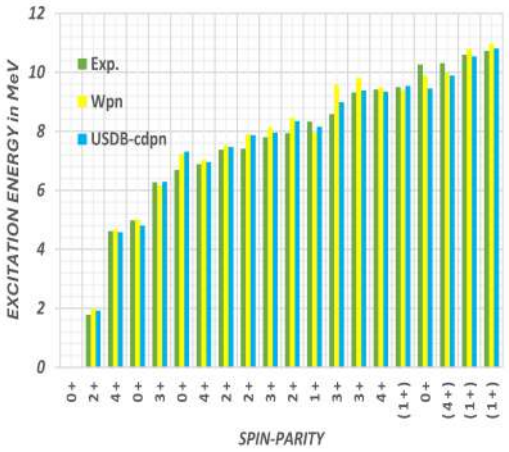

Fig. 1 Theoretical and experimental [6] excitation energies (Ex).

The $1d_{3/2}$ and $1d_{5/2}$ orbitals are meant by (1,3/2) and (1,5/2), respectively. The target nucleus, ^{27}Al has $5/2^+$ as the ground-state spin-parity. It was observed that only ≈ 60% of the total $d_{5/2}$ transfer strength was observed to be associated with the final T = 0 states of spin-parity, 0^+ in ^{28}Si [4]. The authors suggested a small contribution from the $d_{5/2}$ orbital in the summed l = 2 transfer strength for the T = 0 states. The experimental SFs for the states in Table 1 (apart from the yrast 0^+, 2^+, and 4^+ ones and the 6691 keV state) have been taken from the preceding reference, where the contributions of the two *d*-orbitals in forming the final non-zero spin states could not be identified. Single-particle nature is predicted by both Wpn and USDB-cdpn (as the C^2S values are large), alike observation, for the ground state of the residual nucleus, ^{28}Si associated with a proton-capture by the $d_{5/2}$ orbital. However, the results are quite larger than the observed value, 2.640. The order of the 0_3^+ and 4_2^+ states is changed in the calculations with each Hamiltonian. Although the Hamiltonians overpredict the excitation energy of the former state by more than 500 keV, the spectroscopic

Table 1: The calculated spectroscopic factors with NushellX code [8] compared to the experimental results obtained from ^{27}Al(^{3}He, d)^{28}Si reactions [3,4,7] for the low lying positive-parity structure consisting of four states per spin in ^{28}Si.

J^{π}	Ex (MeV)	C^2S (Exp.) l_p		C^2S (Wpn) l_p,j_p			C^2S (USDB-cdpn) l_p,j_p		
		0	**2**	**0,1/2**	**2,3/2**	**2,5/2**	**0,1/2**	**2,3/2**	**2,5/2**
0^+	0.000		2.640			3.617			3.559
2^+	1.779	0.460	0.084	0.391	0.089	0.037	0.395	0.096	0.042
4^+	4.618		0.213		0.218	0.002		0.228	0.007
0^+	4.980		0.670			0.362			0.360
3^+	6.276	0.226	0.404	0.157	0.112	0.012	0.149	0.121	0.008
0^+	6.691		<0.040			0.005			0.009
4^+	6.888		0.610		0.150	0.019		0.159	0.016
2^+	7.381	0.004	0.130	0.005	0.014	0.094	0.005	0.023	0.091
2^+	7.416	0.010	0.130	0.000	0.021	0.001	0.002	0.016	0.000
3^+	7.799	0.141	0.106	0.018	0.002	0.023	0.032	0.001	0.033
2^+	7.933	0.154	0.350	0.000	0.078	0.039	0.062	0.198	0.026
1^+	8.328		0.103		0.130	0.002		0.079	0.004
3^+	8.589	0.524	0.630	0.267	0.008	0.034	0.138	0.236	0.023
3^+	9.316	0.690	0.183	0.085	0.193	0.016	0.223	0.033	0.025
4^+	9.417	NA			0.000	0.017		0.0001	0.027
(1^+)	9.496	0.053	0.847		0.212	0.016		0.259	0.014
0^+	10.272		0.180			0.012			0.022
(4^+)	10.311		0.042		0.000	0.006		0.001	0.002
(1^+)	10.596		0.203		0.089	0.001		0.051	0.016
(1^+)	10.725		0.040		0.001	0.003		0.005	0.014

factor (SF) is correctly reproduced. Except for a few states, the energies provided by the chosen Hamiltonians are in good agreement. For the states at 1779 keV, 4618 keV, 6691 keV and 7381 keV, the reproduced SFs are nearly close to the observed data.

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