B(E2; $5/2^- \rightarrow 1/2^-$) in ^{17}N and ^{17}Ne

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(Received 8 November 2017; published 17 January 2018)

A simple model of E2 strengths previously applied to several neutron-excess light nuclei is used to investigate the $1/2^- \rightarrow 5/2^-$ transition strength in ^{17}Ne, with the aid of mirror symmetry. The calculation is found to be in good agreement with results of a recent measurement and emphasizes a likely problem with the same transition in ^{17}N.

DOI: 10.1103/PhysRevC.97.014308

I. INTRODUCTION

I recently performed an analysis [1] of E2 transition strengths [2–7] in several neutron-excess light nuclei. Transitions were chosen so that the J^π values excluded the possibility of M1 competition. The included nuclei were those with one or two *sd*-shell neutrons outside a *p*-shell core, so that a reasonable assumption was that the transitions involved only neutrons. Transitions were of the type $1d_{5/2} \leftrightarrow 2s_{1/2}$ or $(sd)^2{}_2 \leftrightarrow (sd)^2{}_0$. Given information from ^{17,18}O, a combination of weak coupling and the shell model allowed parameter-free predictions for E2 transitions in ^{16,17}N and ^{15,16}C. Results for those four nuclei are summarized in Table I and plotted in Fig. 1. Agreement between experimental and predicted strengths is reasonable for all four nuclei, but agreement is worst for ^{17}N.

A realistic shell-model calculation [8] for ^{17}N also predicted a B(E2) significantly larger than the current experimental value [exp/shell-model = 0.68(13)], prompting me to suggest [1] "a remeasurement of the ^{17}N gamma width might be warranted."

II. CALCULATIONS AND RESULTS

Because of mirror symmetry, information from ^{17}Ne should help in assessing the ^{17}N problem. However, in ^{17}Ne, the $5/2^-$ state is unbound and decays by *2p* emission, making a measurement of gamma width difficult. But, the inverse B(E2) transition strength can be deduced from Coulomb excitation measurements. Such experiments have been done. The relevant equations are

$$2\,B(\mathrm{E2};1/2^- \rightarrow 5/2^-) = 6\,\mathrm{B}(\mathrm{E2};5/2^- \rightarrow 1/2^-);$$

$$\mathrm{B}(\mathrm{E2\,in}^{17}\mathrm{Ne}) = (\mathrm{e_p}/\mathrm{e_n})^2\,\mathrm{B}(\mathrm{E2\,in}^{17}\mathrm{N}).$$

By consideration of B(E2)'s and quadrupole moments in ^{17}O/^{17}F, Lawson *et al.* [9] determined effective charges of $e_p = 1.5e, e_n = 0.5e$ in the *sd* space. I use those values here. Thus, the expected B(E2; $1/2^- \rightarrow 5/2^-$) in ^{17}Ne is 109 e^2fm^4 (Table II).

Recently, Marganiec *et al.* [10] studied dissociation of relativistic ^{17}Ne projectiles incident on targets of lead, carbon, and polyethylene, paying special attention to the excitation and decay of narrow resonant states in ^{17}Ne. Comparison of data from the heavy and light targets yielded cross sections and transition probabilities for the Coulomb excitations of these narrow states. In particular, the subsequent analysis produced a B(E2) value for $1/2^- \rightarrow 5/2^-$ of 90(18)e^2fm^4. Those authors stated that their B(E2) suggested that the s^2 intensity in ^{17}Ne ground state (g.s.) was either $23^{+9}{}_{-6}$ or $53^{+5}{}_{-9}$%, where I have read the uncertainties from their graph (their Fig. 7). The

TABLE I. E2 transition strengths in relevant nuclei.[a]

Nucleus	J_i^π	J_f^π	B(E2) (e^2fm^4) Calculated		Measured
			$e_n = 0.5e$	$e_n = (Z/A)e$	
^{17}N	$5/2^-$	$1/2^-$	4.02	3.52	2.25(44)[b]
^{16}N	0^-	2^-	4.25	3.66	4.25(5)[b]
^{16}C	2^+	0^+	4.05	3.00	3.50(30)[c]
^{15}C	$5/2^+$	$1/2^+$	1.40	1.03	0.98(2)[d]

[a] Nuclei that have one or two sd-shell neutrons outside a p-shell core [1].
[b] Reference [2].
[c] Simple average of four most recent values [4–7].
[d] Reference [3].

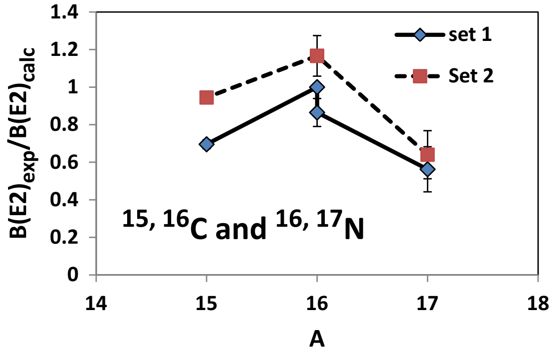

FIG. 1. Ratios of experimental to calculated E2 transition strengths [1] in ^{15,16}C and ^{16,17}N are plotted vs. A. Points labeled Set 1 were obtained with a neutron effective charge of $e_n = 0.5e$; Set 2 used $e_n = (Z/A)e$, where Z and A refer to the core.

TABLE II. Experimental and calculated values ($e^2\mathrm{fm}^4$) of B(E2; $1/2^- \rightarrow 5/2^-$) in ^{17}Ne.

Source	Reference	B(E2)
Calculated	Present	109
Experimental	[10]	90(18)
	[17]	124(18)
	[17] corrected by [10]	179(26)

TABLE III. Wave function of ^{17}N and ^{17}Ne (g.s.) from various sources.

Source	s^2 occupancy	Reference
Shell model calculation[a]	0.28 s^2	[11]
Interaction cross section	Mostly s^2	[12]
Three-cluster calculation	Predominantly s^2	[13]
Coulomb energies	Mostly s^2	[14]
$\beta\pm$ decays of ^{17}N and ^{17}Ne	0.15 s^2 in ^{17}N, 0.22 in ^{17}Ne	[15]
^{17}N/^{17}Ne mirror energy difference	0.22 s^2 in both ^{17}N and ^{17}Ne	[16]
B(E2) in ^{17}Ne	$0.23^{+0.09}{}_{-0.06}$ or $0.53^{+0.05}{}_{-0.09}$	[10]

[a] Gave good agreement with ^{15}N(t,p).

smaller of their two values is consistent with our shell-model value of 0.284 [11]. Several other works [12–14] had suggested dominance of s^2 in this state. Ozawa *et al.* [12] concluded that the experimental value of the ^{17}Ne interaction cross section required that the g.s. has protons mostly in the $s_{1/2}$ orbit. Timofeyuk *et al.* [13] used a three-cluster ($^{15}\mathrm{O} + \mathrm{p} + \mathrm{p}$) generator coordinate model and concluded that the last two neutrons in ^{17}N and the two external protons in ^{17}Ne occupy $s_{1/2}$ states rather than $d_{5/2}$. Nakamura *et al.* [14] computed Coulomb energies for the $A = 17, T = 3/2$ isobaric quartet. They concluded that the "last two protons in ^{17}Ne (g.s.) occupy the $s_{1/2}$ orbit." However, Millener [15], in addressing the asymmetry in $\beta\pm$ decays of ^{17}N and ^{17}Ne, found dominance of d^2 over s^2 configurations. His s^2 occupancies were 0.15 in ^{17}N and 0.22 in ^{17}Ne, whereas the other workers assumed the same configuration amplitudes for the mirror nuclei. Sherr and I computed the ^{17}N/^{17}Ne mirror energy difference as a function of the s^2/d^2 ratio and concluded a value of 0.22 for the s^2 occupancy [16]. These g.s. results are summarized in Table III.

An earlier study of Coulomb excitation [17] yielded an E2 strength of 124(18) $\mathrm{e}^2\mathrm{fm}^4$ for this transition in ^{17}Ne. Reference [10] stated that this value should be corrected to 179(26) $\mathrm{e}^2\mathrm{fm}^4$ because of an error of a factor of e^2. The various experimental strengths are listed in Table II. Reference [10] suggested that the incorrectly large strength in Ref. [17] might have been caused by the assumption of pure Coulomb excitation, when in fact nuclear excitation also contributes.

We note that the most recent B(E2) in ^{17}Ne is in good agreement with my prediction, whereas the earlier value (if the proposed correction is valid) disagrees. This agreement in ^{17}Ne increases the likelihood that the experimental B(E2) in ^{17}N is too small and strengthens the argument that this gamma width should be remeasured. It appears that the old ^{17}N strength depends solely on a branching ratio of 0.78(3) and a single measurement of the mean life of 11(2) ps, using the recoil-distance technique [18].

III. SUMMARY

In summary, a recent measurement of B(E2; $1/2^- \rightarrow 5/2^-$) in ^{17}Ne is in good agreement with the calculation in a simple model that combines weak coupling, the shell model, and mirror symmetry. The s^2 occupancy of ^{17}Ne (g.s.) that is deduced from the measured value is also in agreement with our earlier wave function. Results indicate that the corresponding strength in ^{17}N should be remeasured.

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