Comment on "Reduction of the Spin-Orbit Splittings at the $N = 28$ Shell Closure"

Gaudefroy *et al.* discuss the behavior of the spin-orbit splitting in ^{49}Ca and ^{47}Ar based upon recent data for states observed in the ^{46}Ar$(d, p)^{47}$Ar reaction [1]. They deduce a 0.89(13) MeV reduction in the $p_{3/2} - p_{1/2}$ spin-orbit splitting for Ar ($Z = 18$) compared to Ca ($Z = 20$). We show that there is a significant fragmentation of the p-shell spectroscopic strength between ^{45}Ar and ^{47}Ar which must be taken into account when evaluating the single-particle energy shifts.

The calculations for ^{47,48,49}Ca and ^{45,46,47}Ar were carried out using OXBASH [2] and the *sdpf* interaction from [3], where proton excitations are restricted to the *sd* shell and neutron excitations are restricted to the *pf* shell. This is the same calculation carried out in [1], and as shown in that Letter the calculated level scheme for ^{47}Ar is in reasonably good agreement with experiment. In both ^{47}Ar and ^{49}Ca the first excited state is a $1/2^-$ state with the experimental (theoretical) excitation energies of 2.02 (1.70) MeV for ^{49}Ca and 1.13(8) (1.28) MeV for ^{47}Ar. Gaudefroy *et al.* deduce a reduction of spin-orbit splitting around the $N = 28$ shell closure as a result of this decrease in excitation energy. However, in general one should use the single-particle centroid energies for the $p_{1/2}$ and $p_{3/2}$ orbits that include both particle and hole strength [4]:

$$\epsilon = \frac{\sum_f (E_o - E_f^-) C^2 S_f^- + (2J_f + 1)(E_f^+ - E_o) C^2 S_f^+}{\sum_f C^2 S_f^- + (2J_f + 1) C^2 S_f^+}, \tag{1}$$

where S^+ refers to the ^{46}Ar → ^{47}Ar direction, S^- refers to the ^{46}Ar → ^{45}Ar direction, and $C^2 S_f$ are the spectroscopic factors. For all final nuclei, 200 final states were included; this is enough to exhaust 100.0% (Ca $p_{1/2}$), 100.0% (Ca $p_{3/2}$), 99.3% (Ar $p_{1/2}$) and 99.4% (Ar $p_{3/2}$) of the $(2j + 1)$ spectroscopic sum-rule limit. As seen in Fig. 1, the lowest-energy states in ^{49}Ca account for 95% of the total spectroscopic strength for the $p_{1/2}$ and $p_{3/2}$ orbits, whereas the lowest-energy states in ^{47}Ar account for only 80% and 65%, respectively, of the total strength. We are interested in the change of the spin-orbit splitting: $\delta\epsilon_{\rm so} = [\epsilon({\rm Ar}, p_{3/2}) - \epsilon({\rm Ar}, p_{1/2})] - [\epsilon({\rm Ca}, p_{3/2}) - \epsilon({\rm Ca}, p_{1/2})]$. Given that there is some difference between experiment and theory for the energies of the lowest $3/2^-$ and $1/2^-$ states in ^{47}Ar and ^{49}Ca (as noted above), we estimate $\delta\epsilon_{\rm so}$ by starting with the experimental shift for the lowest $3/2^-$ and $1/2^-$ states observed between ^{49}Ca and ^{47}Ar, $-0.89(13)$ MeV [1], and adding a theoretical correction due to fragmentation (with theoretical energies for other nuclei and states), $+0.88$ MeV, to obtain $\delta\epsilon_{\rm so} = -0.01(13)$ MeV (method a). Another procedure would be to use the experimental binding energies for all of the known nuclei and states in Eq. (1) together with theoretical excitation energies relative to these to obtain $\delta\epsilon_{\rm so} = +0.09(13)$ MeV (method b).

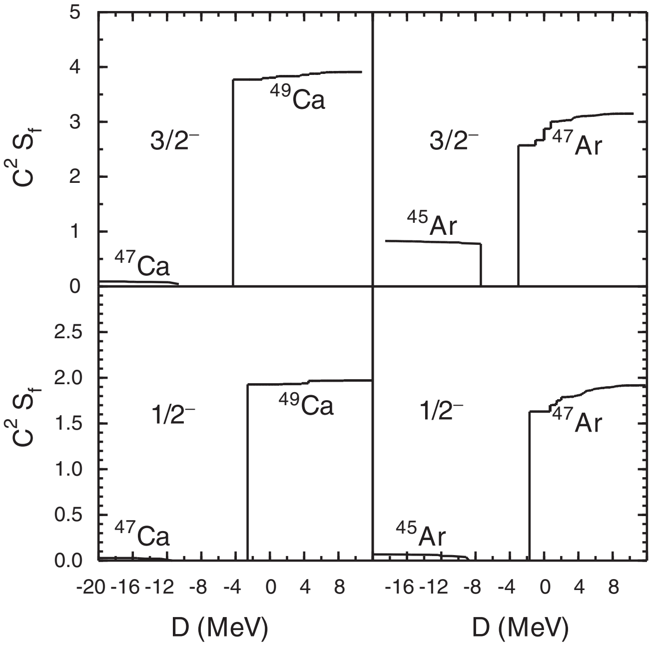

FIG. 1. Spectroscopic factors summed up to energy $D = \pm(E_f^{\mp} - E_o)$ for the ^{48}Ca core (left) and ^{46}Ar core (right). The $C^2 S$ for the hole state as a function of increasing excitation energy in ^{47}Ca and ^{45}Ar run to the left, and the $(2J_f + 1)C^2 S$ for the particle states in ^{49}Ca and ^{47}Ar run to the right.

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