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Configuration of ^{13}B(g.s.)

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We use recent results of β-delayed neutron emission from ^{14}Be to estimate the configuration of the ground state of ^{13}B. We also discuss consequences for ^{14}Be and ^{14}B.

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Aoi *et al.* [1] observed the Gamow-Teller β decay of ^{14}Be(g.s.) to a 1^+ level at 1.28 MeV in ^{14}B, followed by emission of a neutron to the $\frac{3}{2}^{-}$ ^{13}B(g.s.). From the measured neutron width of the ^{14}B level, they were able to estimate the ^{13}B(g.s.) configuration mixing, and hence the $s_{1/2}$-$p_{1/2}$ energy splitting in that nucleus.

Here, we investigate their findings in our model of these nuclei. In what follows, we couple 1–4 nucleons to a ^{10}Be core to make the nuclei from ^{11}Be to ^{14}Be, ^{14}B. But to keep the nomenclature simple, we refer everything to a "^{12}C" core—nominally a closed $p_{3/2}$ subshell—though in reality, of course, some $p_{1/2}$-$p_{3/2}$ mixing is present. Hence, ^{10}Be(g.s.) is $\pi(p_{3/2})^{-2}$ and ^{12}Be(g.s.) is $\pi(p_{3/2})^{-2}\nu[\alpha(sd)^2+\beta(1p)^2]$.

In Ref. [2], we estimated the fraction of s^2 in the ^{12}Be(g.s.) to be 0.53 ± 0.02. With single-particle energies from ^{11}Be and two-body matrix elements from this mass region [3], we suggested that $(sd)^2$ contained 22%d^2 and 78%s^2, giving $\alpha^2=0.67$, $\beta^2=0.33$ for ^{12}Be(g.s.). In the reaction ^{9}Be(^{12}Be,^{11}Be), Navin *et al.*, [4] measured spectroscopic factors of 0.53 ± 0.13 for $2s_{1/2}$ and 0.45 ± 0.12 for $1p_{1/2}$, with $1d$ unobservable in their experiment. Of course, as the sum of the relevant spectroscopic factors has a maximum value of 2.0, significant strength is missing. It is unlikely that most of it resides in the missing d wave. The authors stated that the ratio of spectroscopic factors is well determined by their experiment. They concluded that matching the ratio of spectroscopic factors requires an admixture of about 32%$(1p)^8$ and 68%$(1p)^6(2s,1d)^2$, in remarkable agreement with our earlier paper.

We expect the neutron configuration of ^{13}B to be similar, but with only one $p_{3/2}$ proton hole, i.e., ^{13}B(g.s.) is $\pi(p_{3/2})^{-1}[A(sd)^2+B(1p)^2]$. Weak-coupling considerations would suggest $A\approx\alpha$, $B\approx\beta$, but we know that the $s_{1/2}$-$p_{1/2}$ energy splitting in ^{12}B is much different from what it is in ^{11}Be. This shifting of sp energies will affect the mixing somewhat. Our present aim is to estimate A,B for ^{13}B(g.s.).

In ^{14}B, the low-lying 1^-, 2^- states are presumably predominantly $\pi(p_{3/2})^{-1}\nu[(1p)^2s]$. Guimarães *et al.* [5] estimated the ^{14}B(g.s.) to be $89\pm3\%$ s, $11\pm3\%d$. The 1^+ (and missing 2^+) levels should be dominantly $\pi(p_{3/2})^{-1}\nu[(sd)^2 1p]$. Hence, the decay ^{14}B$(1^+)\to{}^{13}$B(g.s.) is proportional to A^2. The factor A^2 multiplies a spectroscopic factor that should be similar to that for ^{12}B$(1^+)\to{}^{11}$B(g.s.), with $\pi(p_{3/2})^{-1}\nu(sd)^2$ acting as spectators, i.e.,

$$S[^{14}\mathrm{B}(1^+)\to{}^{13}\mathrm{B(g.s.)}+n]\cong A^2S[^{12}\mathrm{B}(1^+)\to{}^{11}\mathrm{B(g.s.)}+n].$$

This ^{12}B spectroscopic factor has been measured [6] to be 0.69, and calculated by Cohen and Kurath [7] to be 0.826, of which 0.708 is $p_{1/2}$.

Thus, we expect the ^{14}B(1^+) decay spectroscopic factor to be (0.7–0.8) A^2. The measured neutron width [1] for this $\ell=1$ decay is 49 keV, and the center-of-mass neutron energy is 310 keV. We will compute S from $S=\Gamma_{\mathrm{n}}/\Gamma_{\mathrm{sp}}$, where Γ_{sp} is calculated in a potential well with $r_0=1.25$ fm, $a=0.65$ fm, and whose depth is adjusted to fit the observed neutron energy. The neutron energy of 310 keV is sufficiently unbound such that various definitions of sp width provide somewhat different values. For present purposes, we define the resonant energy to have a phase shift δ of $\pi/2$ and the sp width to be obtained from the equation $2/\Gamma_{\mathrm{sp}}=d\delta/d\mathrm{E}$. With this definition, we get $\Gamma_{\mathrm{sp}}=216$ keV—giving $S=0.23$. Hence, $A^2\approx0.28$–0.32. A similar argument in Ref. [1] gave $A^2\approx0.33$, but they used an R-matrix sp width of 160 keV, and they did not use the ^{12}B→^{11}B reduction factor.

The nature of ^{14}Be(g.s.) is also of interest. We expect $\pi(p_{3/2})^{-2}\nu\,[A'(sd)^4+B'\,(sd)^2p^2]$. In order for the β decay from ^{14}Be(g.s.) to ^{14}B(1^+) to be as strong as observed [1] ($\log ft=3.68\pm0.05$), the second term should be greater than the first. The fact that ^{12}Be→^{12}B β decay is slower than that calculated was used [8] as evidence for $(sd)^2$ configurations in ^{12}Be(g.s.). In ^{12}Be, the experimental $\log ft$ [6] is 3.834 ± 0.017, whereas p-shell calculations [8,9] provide values of 3.4–3.5. Suzuki and Otsuka conclude that "65% breaking of the neutron p-shell closure" is necessary to explain the decay rate. Their value of 35% is to be compared to our $\beta^2=0.33$ in Ref. [2].

We can also compute the spectroscopic factor for proton stripping on ^{12}Be to produce ^{13}B(g.s.) [or proton knockout from ^{13}B(g.s.) to form ^{12}Be]:

$$S[^{12}\mathrm{Be}+p\to{}^{13}\mathrm{B(g.s.)}]=(A\alpha+B\beta)^2[^{10}\mathrm{Be}+p\to{}^{11}\mathrm{B(g.s.)}].$$

The latter factor is calculated [7] to be 0.645. With our wave functions, the first factor is 0.86. Hence, we expect S for

^{12}Be→^{13}B to be 0.56. Millener [10] estimated this quantity to be 0.52. This prediction should be testable with radioactive beams.

The experimental width of 49 ± 2 keV in Ref. [1] was extracted from a modified Gaussian fit to their time-of-flight spectrum. We estimate that a fit of the energy spectrum to a Breit-Wigner shape appropriate to an unbound state with natural width, folded with the experimental resolution, would produce $\Gamma=34\pm3$ keV. If we use this width in our calculations, our value of A^2 changes from 0.28–0.32 (with $\Gamma=49$ keV) to 0.20–0.22, and our predicted ^{12}Be→^{13}BS becomes 0.51, rather than 0.56.

As mentioned above, the ground state (g.s.) of ^{12}Be appears to contain about 67%$(sd)^2$ [2,4]. In ^{14}C, the ratio of ^{12}C(t,p) cross sections leading to the g.s. and first-excited 0^+ state provided an estimate [11] of (12 ± 2)% for the amount of $(sd)^2$ in ^{14}C(g.s.). Our result above for ^{13}B(g.s.) lies between the values for ^{14}C and ^{12}Be. Hence, in these $N=8$ nuclei, the amount of $(sd)^2$ in the g.s. increases dramatically as A decreases.

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