# Mass of $^{11}$O

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A recent parametrization of two-proton separation energies in O and Ne nuclei allows a prediction of the energy of $^{11}$O(g.s.): $S_{2p} = -5.41(11)$ MeV, which is considerably more unbound than another recent estimate.

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I recently considered a series of $N = 8$ and 10 neutron-excess nuclei and their $Z = 8$ and 10 proton-excess mirrors [1]. The $N = 8$ and 10 nuclei included were those whose ground states (g.s.) consisted of a two-neutron configuration-mixed $0^+$ pair coupled to a predominantly $p$-shell core. The mirror energy difference (MED) was defined as the difference between the two-neutron separation energy in the neutron-excess nucleus and the two-proton separation energy in the proton excess mirror:

$$\mathrm{MED} = S_{2n}(\text{neutron-excess nucleus}) - S_{2p}(\text{proton-excess mirror}).$$

I noted that these MED's could be well described by a simple parametrization,

$$\mathrm{MED} = [a + bS_{2n} - cP(s^2)]Z_</A^{1/3},$$

where $P(s^2)$ is the fractional parentage in the $2s_{1/2}$ orbital, normalized such that $P(s^2) + P(d^2) + P(p \text{ shell}) = 1$, and $Z_<$ is 6 and 8 for O and Ne nuclei, respectively. Values of $S_{2p}$ computed [1] from the fit agreed remarkably well with experimental $S_{2p}$'s [2]. I used the fit to estimate $P(s^2)$ for $^{13}$B and to predict the mass excess of $^{15}$Ne(g.s.). Here, I apply the procedure to the $^{11}$Li/$^{11}$O mirror pair.

The nucleus $^{11}$Li [3] is by far the most studied of the so-called halo nuclei. Most treatments consider it as a loosely bound $2n$ pair ($S_{2n} = 0.369$ MeV [2]) coupled to a $p$-shell $^9$Li core. Calculations and opinions vary as to the amount of $s^2$ in the $2n$ wave function and as to whether a $d^2$ component should be included. A recent summary [4] included the relevant references. Estimates of $P(s^2)$ vary from about 0.23 to about 0.50, although values of 0 and 1 have also been considered. Examination of the matter radius [5–7] led us to suggest $P(s^2) = 0.33(6)$ [4]. With this value of $P$ and the fit from Ref. [1], the expected $S_{2p}$ is $-5.41(11)$ MeV. If $P(s^2)$ were 1, the value would be $-4.12$ MeV. These results are listed in Table I.

Charity *et al.* [8] recently observed the double-isobaric-analog state (DIAS) of $^{11}$Li in $^{11}$B at an excitation energy of 33.57(8) MeV. They fitted the masses of the three known $A = 11$, $T = 5/2$ states ($^{11}$Li, $^{11}$Be*, and $^{11}$B**) to the quadratic form of the isobaric multiplet mass equation (IMME) and then used the resulting parameters to compute the mass excess of $^{11}$O. Their result was a mass excess of 46.70(84) MeV, which corresponds to $S_{2p} = -3.21(84)$ MeV (Table I). Their value and mine differ by about 2.6$\sigma$. This large difference is unsettling. Their result is 1.1$\sigma$ away from my result at the extreme of $P(s^2) = 1$. Their use of the quadratic IMME may be somewhat suspect because the masses of the $A = 9$, $T = 3/2$ cores require a small nonzero cubic term ($d \neq 0$). This fact might affect the $^{11}$O calculation.

Because the $^{11}$O energy is so large, and because some of the relevant $^{10}$N states are at relatively lower energy [9], the decay of $^{11}$O will primarily be sequential $2p$ decay through one or more of the $^{10}$N resonances. The decay width will depend sensitively on the $^{11}$O mass and on the energies and widths of the $^{10}$N resonances—at least the lowest two $s$-wave ($1^-$ and $2^-$) and perhaps the two lowest $p$-wave ($1^+$ and $2^+$) resonances. As pointed out by the compilers [9], the $1^+$ is probably the state known [10] at $E_p = 2.64(40)$ MeV. The lowest $s$-wave state should be at about $E_p = 1.8$ MeV [9,11]. Nothing is known about the other two $^{10}$N resonances.

TABLE I. Two-nucleon separation energies (MeV) of $^{11}$Li/$^{11}$O ground states.

| Experimental | | | Calculated | | Reference |
|---|---|---|---|---|---|
| Nucleus | $S_{2n}$[a] | $P(s^2)$ | Nucleus | $S_{2p}$ | |
| $^{11}$Li | 0.369 | 0.33(6)[b] | $^{11}$O | $-5.41(11)$[d] | Present |
| | | 1.0[c] | | $-4.12$[d] | Present |
| | | | | $-3.21(84)$[e] | Charity *et al.* [8] |

[a]Reference [2].
[b]Reference [4].
[c]Limiting value.
[d]From fit in Ref. [1].
[e]Using IMME and energies of lowest $T = 5/2$ states in $^{11}$Li, $^{11}$Be, and $^{11}$B [8].

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