$2n$ decays of ^{16}Be

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I have estimated the decay width of ^{16}Be for a variety of decay mechanisms: $2n$ cluster decay, sequential decay through the known $5/2^+$ state of ^{15}Be, and sequential decay through a hypothetical $1/2^+$ state in ^{15}Be. Only the cluster decay width is comparable to the reported experimental width.

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I. INTRODUCTION

It has been suggested that ^{16}Be decays by simultaneous $2n$ emission—either dineutron or so-called democratic decay. The ground state (g.s.) of ^{16}Be is unbound with respect to $^{14}\text{Be} + 2n$ by 1.35(10) MeV, with a reported width of $0.8^{+0.1}_{-0.2}$ MeV [1]. It was populated by proton removal from ^{17}B, presumably by removal of a $1p_{3/2}$ proton. The experimenters used a Breit-Wigner shape in their analysis, even though the decay (if $2n$) will have L = 0. Marqués *et al.* [2] questioned the $2n$ decay mechanism, and they pointed out that an enhancement at small relative n-n energy and angle is to be expected whatever the decay mechanism is. They concluded that "the inclusion of the n-n interaction in the description of direct three-body decay of ^{16}Be generates strong enhancements at low n-n relative energy and angle and large ^{14}Be-n opening angles, characteristic of those observed by Spyrou *et al.* [1], without the need to invoke dineutron decay." Spyrou *et al.* [3] replied to the comment of Marqués *et al.* [2], but to my knowledge, this question has not yet been resolved.

II. CALCULATIONS AND RESULTS

One argument in favor of $2n$ decay of ^{16}Be is the large width. The only state that is known in ^{15}Be is a $5/2^+$ resonance at 1.8(1) MeV relative to $^{14}\text{Be} + n$, with a width of 0.58(20) MeV [4] (see Fig. 1). The ^{16}Be(g.s.) can decay sequentially through the low-energy tail of this resonance, but Snyder *et al.* [4] estimated this width as $3.5^{+2.5}_{-1.8}$ keV. I have also calculated this width, using the standard convolution procedure [5,6], and I get 4.5 keV for a ^{15}Be width of 0.58 MeV. Of course, a $3/2^+$ (and perhaps $1/2^+$) state is expected in ^{15}Be, but not yet observed. Kuchera *et al.* [7] looked for additional ^{15}Be states in $^{12}\text{Be} + 3n$ coincidences following two-proton removal from ^{17}C, but results were inconclusive. They reported that their data could be understood without invoking the participation of any ^{15}Be states. I have discussed these other expected states elsewhere [8]. If one of these states is below the $5/2^+$, it could serve as an intermediate state in sequential decay, as Snyder *et al.*, suggested. If such a state exists, and it is $3/2^+$, its spectroscopic factor from ^{16}Be(g.s.) would be expected to be quite small, because ^{16}Be(g.s.) contains primarily $2s_{1/2}$ and $1d_{5/2}$ as valence neutrons.

For now, it appears to me that the strongest argument in favor of $2n$ decay is the large decay width. One theoretical estimate of this width is 0.17 MeV [9], which is small compared to the reported experimental value. Lovell *et al.* suggest the difference may be due to experimental resolution, etc. They state, "This discrepancy is most likely due to the effect of experimental resolution (etc.), which has not been taken into account when comparing our calculations with experiment." However, the experimental width they quote [1] is the width of the Breit-Wigner shape that was entered into their fitting program and folded with the experimental resolution width [10]. Here, I have attempted to compute the expected width for $2n$ cluster decay.

The expected widths can be calculated with the expression $\Gamma_{\text{calc}} = S\,\Gamma_{\text{sp}}$, where S is the $2n$ cluster spectroscopic factor for ^{16}Be(g.s.) to $^{14}\text{Be(g.s.)} + 2n$, and Γ_{sp} is the single-particle width for $2n$ cluster decay. Because this decay has L = 0, and the $2n$ cluster has no charge, there is no barrier. In such cases, the sp width varies as $E^{1/2}$. The approximation $\Gamma_{\text{sp}} \sim \hbar/(\text{fly-by time})$ suggests a coefficient near unity in the present case. Thus, for an $(sd)^2$ $L = 0$ $2n$ cluster, I have used $\Gamma_{\text{sp}} = E^{1/2}$, with both energy and width in units of MeV. Spyrou *et al.* [1] list as $(sd)^2$ two-nucleon transfer amplitudes for ^{16}Be to ^{14}Be obtained in a shell-model calculation the values 0.90, 0.33, and 0.34 for $1d^2_{5/2}$, $1d^2_{3/2}$, and $2s^2_{1/2}$, respectively. With these amplitudes, they quote a $2n$ spectroscopic factor of 0.36. In a treatment of the matter radius of ^{18}C [11], which has the same number of neutrons as ^{16}Be, I considered two different configurations for the last two neutrons: $0.367s^2 + 0.633d^2$ and $0.20s^2 + 0.80d^2$, where here the numbers are intensities rather than amplitudes. These two admixtures give $S = 0.37$ and 0.32, respectively—not very different from the S computed from the amplitudes of Spyrou *et al.* For present purposes, I use $S = 0.35$. With an energy of 1.35 MeV, Γ_{sp} is 1.2 MeV, resulting in $\Gamma_{\text{calc}} = 0.41$ MeV—smaller than the experimental value of $0.8^{+0.1}_{-0.2}$ MeV, but significantly larger than the earlier estimate of 0.17 MeV. Of course, the coefficient of $E^{1/2}$ in the expression for $L = 0$ sp width has a considerable uncertainty. I have taken $(3E)^{1/2}$ as representing the outside limit on this coefficient. Then, the $2n$ spectroscopic factor of 0.36 from Ref. [1] and the assumption $\Gamma_{\text{sp}} = (3E)^{1/2}$ gives an expected width of 0.72 MeV.

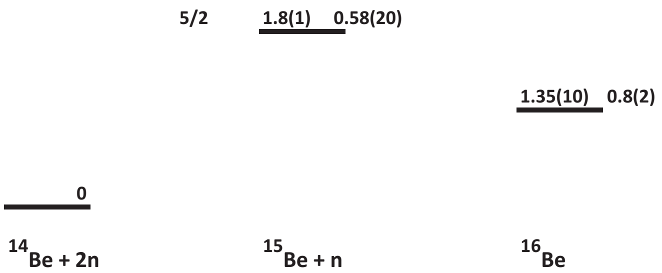

FIG. 1. Energy schematic of ^{14,15,16}Be, exhibiting the g.s. of ^{16}Be and the supposed g.s. of ^{15}Be (with energy and widths given in MeV) relative to ^{14}Be(g.s.).

Another possibility is sequential decay through a presently unknown $1/2^+$ state in ^{15}Be. Because both of these $1n$ decays would be $\ell = 0$, the width could be appreciable, even if the $1/2^+$ state is above the $5/2^+$. (Recall that sequential decay through the $5/2^+$ gave a width of only 4.5 keV.) Using the same convolution procedure, I have computed the expected width for sequential decay through a hypothetical $1/2^+$ state in ^{15}Be—as a function of the assumed energy of this $1/2^+$ state. Results are plotted in Fig. 2. The sequential-decay widths for this energy range of the hypothetical $1/2^+$ state are similar to the $2n$ decay width of 0.17 MeV estimated by Lovell *et al.*

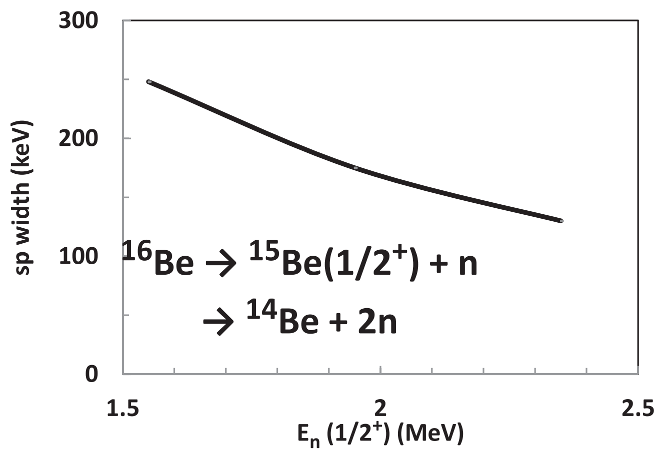

FIG. 2. Calculated single-particle width for sequential decay of ^{16}Be through a hypothetical $1/2^+$ state in ^{15}Be, plotted vs the assumed energy of the $1/2^+$ state (relative to ^{14}Be + n).

III. SUMMARY

I have estimated the width for $2n$ cluster decay of ^{16}Be to the g.s. of ^{14}Be. For a cluster spectroscopic factor of 0.35 and an approximate estimate of an L = 0 "single-particle" width, the calculated width is 0.42 MeV. For comparison, the width for sequential decay through the low-energy tail of the known $5/2^+$ state of ^{15}Be is calculated to be about 4.5 keV. The single-particle width for sequential decay through a hypothetical $1/2^+$ state in the energy range 1.5–2.4 MeV (relative to ^{14}Be + n) is computed to be in the range 130–250 keV (Fig. 2). With a spectroscopic factor product of $S_1 S_2 = 0.4$ or 0.73, this predicted width is thus 100 or 180 keV for a $1/2^+$ energy of 1.5 MeV. It would seem to be important to locate the $1/2^+$ state and measure its width.

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