Decays of ^{15}Be($5/2^+$)

H. T. Fortune
Department of Physics and Astronomy, University of Pennsylvania, Philadelphia, Pennsylvania 19104, USA

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I have computed spectroscopic factors S and single-particle widths Γ_{sp}, and hence expected decay widths $\Gamma_{calc} = S\Gamma_{sp}$ for decay of the lowest $5/2^+$ state of ^{15}Be to the ground state and first 2^+ state of ^{14}Be. Results indicate that decay to the 2^+ state should be appreciable.

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I. INTRODUCTION

The apparent ground state (g.s.) of ^{15}Be has been identified as a $5/2^+$ resonance that decays to $^{14}\text{Be} + n$ with an energy of 1.8(1) MeV and a width of 0.58(20) MeV [1]. It was produced by neutron addition to ^{14}Be and observed by detecting ^{14}Be and n in coincidence. Most calculations predict a $3/2^+$, and perhaps a $1/2^+$, state nearby, but they have never been observed. At present, it is unclear if the $5/2^+$ is the g.s., or if another state exists below it. The failure to observe any other states in ^{15}Be remains a bit of a puzzle.

Earlier [2], I examined the properties of the lowest $5/2^+$ state in ^{15}Be in a simple model [3] that has been shown to work well for other core + $3n$ nuclei. In ^{17}C and ^{19}O, the model reproduces the absolute energy of the lowest $5/2^+$ state to within 60 keV in ^{17}C and 100 keV in ^{19}O [2]. In these two cases, the s and d single-particle energies (spe's) are well known in ^{15}C and ^{17}O. However, for ^{15}Be, the spe's in ^{13}Be are poorly known. I thus used the observed $5/2^+$ energy of 1.8 MeV in ^{15}Be [1] to put constraints on the s and d spe's in ^{13}Be [2]. I discussed two separate solutions from the allowed continuous range of E_s vs E_d.

The reported width for ^{15}Be($5/2^+$) of 0.58(20) MeV has a large uncertainty, but I pointed out that its central value was considerably larger than expected [2]. Earlier [4], I suggested that several neutron-decay widths obtained from decay-in-flight experiments appear to be too large by a factor of about 1.6. Another possibility is that some of the width comes from decay of the $5/2^+$ state to the first 2^+ state at 1.54 MeV in ^{14}Be. Here, I explore that possibility further.

II. CALCULATIONS AND RESULTS

Relevant energies are depicted in Fig. 1. For $\ell = 2$ decay of the $5/2^+$ state to the 0^+ g.s., I have computed the single-particle (sp) width in a Woods-Saxon potential well, having geometric parameters of $r_0, a = 1.26,\ 0.60$ fm. At an energy of 1.8 MeV, this sp width is 0.46 MeV. For $\ell = 0$ decay of the $5/2^+$ state to the 2^+ first-excited state, the absence of a barrier for s-wave neutron resonances is a complication. These widths should vary as $E^{1/2}$. With no barrier, a "sp width" can be approximated as $\hbar$ divided by the fly-by time, so that $\Gamma_{sp} \sim \hbar v/D$, where v is the speed of the projectile and D is some measure of the diameter of the nucleus. With $E = mv^2/2,\ D = 2r_0A^{1/3}$, and $r_0 = 1.3$ fm, the result is $\Gamma_{sp} \sim (2E)^{1/2}$, where I have used the fact that $\hbar^2/(2m_n) = 20.7$ in the Mev-fm-amu system of units. Thus, for present purposes, I have used $\Gamma_{sp}(\ell = 0) = (2E)^{1/2}$. Then, for the decay being considered, the sp width is 0.72 MeV. Because of the low energy of this decay, $\ell = 2$ decay can be ignored.

With these sp widths, the expected widths can be calculated with the expression $\Gamma_{calc} = S\Gamma_{sp}$, where S is the spectroscopic factor. For these, I have used the wave functions from my two solutions for the $^{12}\text{Be} + 3n$ calculation [2]. Because those two solutions had different E_s and E_d in ^{13}Be, the wave functions for 0^+ and 2^+ are also different. Results are listed in Tables I and II. An analysis [5] of $2n$ decays [6] of the first 2^+ state of ^{14}Be implied that its structure was $0.84(sd)^2$ and $0.16(sd)^4$. I have used that result here.

Snyder *et al.* [1] quote a spectroscopic factor of 0.44 and a sp width of 0.40 keV for the g.s. decay. My S is considerably larger for both sets of wave functions, but the calculated g.s. decay width is still smaller than the central value of the experimental width. It can be noted that decay to the 2^+ state cannot be ignored. With both sets of wave functions, it is calculated to be an appreciable fraction of the total. Comparison with the experimental value implies a slight preference for Solution 2, but not overwhelmingly so. A very recent paper on ^{13}Be [7] reports an energy of 0.86(4) MeV and a width of 1.70(15) MeV for the $1/2^+$ resonance and an energy of 2.11(5) MeV for $5/2^+$.

Of course, because the 2^+ state is unbound with respect to $^{12}\text{Be} + 2n$, decay to it results in a $^{12}\text{Be} + 3n$ final state. In a

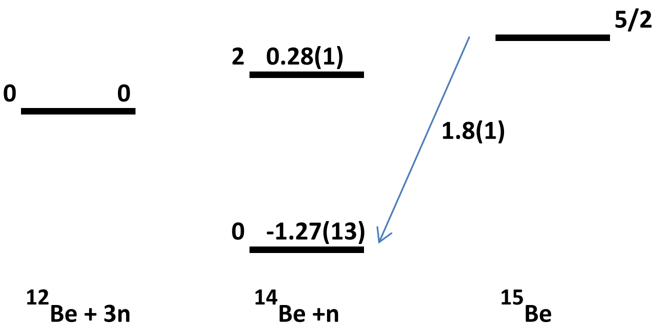

FIG. 1. The $5/2^+$ state in ^{15}Be and relevant states in ^{14}Be and ^{12}Be.

TABLE I. Results of two solutions to the ^{15}Be$(5/2^+) = {}^{12}$Be + 3n problem [2].

Quantity	Solution 1	Solution 2
E_s (MeV)	∼0	0.50
E_d (MeV)	2.3	1.88
^{14}Be$(sd)^2$ 0^+	$0.85s^2$, $0.15d^2$	$0.41s^2$, $0.59d^2$
^{14}Be$(sd)^2$ 2^+	$0.92ds$, $0.08d^2$	$0.81ds$, $0.19d^2$
^{15}Be$(sd)^3$ $5/2^+$	$0.14d^3$, $0.01d^2s$, $0.85ds^2$	$0.59d^3$, $\sim 0d^2s$, $0.41ds^2$

search for the $3/2^+$ state of ^{15}Be, Kuchera *et al.* [8] looked for ^{12}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. However, 2p removal from the $3/2^+$ g.s. of ^{17}C would not be expected to strongly populate the $5/2^+$ state of ^{15}Be, even though it might be the best candidate for making the $3/2^+$ state. It would be worthwhile to look for ^{12}Be + 3n decays following an experiment that strongly populates this state. Adding a neutron to ^{14}Be, as in the original work [7], is probably the most promising such reaction for making the $5/2^+$ state. Those authors did not have the ability to examine 3n events at the time [9]. Another possibility might be ^{14}C(^{16}C, ^{15}O) ^{15}Be. As a "stable" beam experiment, the reaction ^{14}C(^{14}C, ^{13}O) ^{15}Be might be worth a look. A smaller uncertainty on its width would also be welcome.

III. SUMMARY

Using wave functions from an earlier treatment of the lowest $5/2^+$ state of ^{15}Be [2], I have computed spectroscopic factors and expected widths for decay of this state to the 0^+ g.s. and 2^+ first-excited state of ^{14}Be. The predicted width for decay to the 2^+ state turns out to be an appreciable fraction of the total.

TABLE II. Widths (MeV) and spectroscopic factors for decay of ^{15}Be$(5/2^+)$ to lowest 0^+ and 2^+ states of ^{14}Be.

Source	Decay to 0^+ via $\ell = 2$			Decay to 2^+ via $\ell = 0$			Γ_{calc} (tot)	Γ_{exp}
	Γ_{sp}	S	Γ_{calc}	Γ_{sp}	S	Γ_{calc}		
Solution 1 [2]	0.46	0.94	0.43	0.72	0.55	0.39	0.82	0.58(20)
Solution 2 [2]	0.46	0.80	0.37	0.72	0.23	0.17	0.54	
Reference [1]	0.40	0.44	0.18	NA	NA	NA	0.18	

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