12-13-2012

Branching Ratio of ^{18}Ne(7.06 MeV, 4$^+$)

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Fortune, H. T. (2012). Branching Ratio of ^{18}Ne(7.06 MeV, 4$^+$). *Physical Review C, 86*(6), 068802. doi: 10.1103/PhysRevC.86.068802

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Abstract

The recently reported branching ratio (BR) for the 4^+ state in ^{18}Ne at $E_x = 7.06$ MeV strongly disagrees with the BR computed using the known properties of this state.

Disciplines

Physical Sciences and Mathematics | Physics

Comments

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PHYSICAL REVIEW C **86**, 068802 (2012)

Branching ratio of ^{18}Ne(7.06 MeV, 4$^+$)

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(Received 19 August 2012; published 13 December 2012)

The recently reported branching ratio (BR) for the 4^+ state in ^{18}Ne at $E_x = 7.06$ MeV strongly disagrees with the BR computed using the known properties of this state.

DOI: 10.1103/PhysRevC.86.068802 PACS number(s): 26.20.−f, 26.50.+x, 21.10.Jx, 27.20.+n

There appears to be a serious problem with at least one of the proton branching ratios (BR's) recently reported [1] for astrophysically interesting states near 5–8 MeV in ^{18}Ne. Almaraz-Calderon *et al.* [1] populated these states with the ^{16}O(^{3}He,n) reaction and detected the decay protons. Their reported BR's for the 4^+ state at 7.06(10) MeV are listed in Table I. At temperatures above about $T_9 \sim 2$, this resonance is the most important for the reaction ^{14}O(α,p). Yet the proton branching ratios are in some considerable disagreement. Sometimes the cross section for the reaction ^{14}O(α,p) is obtained by applying detailed balance to a measured cross section for the time-reversed reaction ^{17}F(p,α). The presence of p_1 decays invalidates that procedure.

Harss *et al.* [2] initially assigned 1^- to a state at 7.16(15). We proved it was 4^+ [3]. They later agreed [4] and gave $E_x = 7.05(10)$. Our calculated energy and alpha width were 7.086(40) MeV [5] and 22.6(3.2) eV [6]. This state should not have a measureable p_1 decay for reasons I now discuss. The largest component in the structure of this state [7] (see Table II) is a collective excitation that is primarily of a four-particle two-hole ($4p$-$2h$) configuration, i.e., $(sd)^4(1p)^{-2}$, where the $(sd)^4$ part is basically the first 4^+ state of ^{20}Ne. By use of mirror correspondence, we had earlier calculated the expected energy and proton and alpha widths [3,5,6]. They are listed in Table III. The problem with the new BR is the reported branch to the $1/2^+$ excited state of ^{17}F. In order for a 4^+ state to decay to $1/2^+$, the ℓ value must be 4. This 4^+ state is very unlikely to have any appreciable $g_{9/2}$ strength. Furthermore, because of the large centrifugal barrier the maximum $\ell = 4$ width is very small. With standard parameters $r_0 = 1.26$, $a = 0.60$, $r_{0c} = 1.40$ (all in fm), I get $\Gamma_{sp}(\ell = 4) = 0.68$ keV for 4^+ to $1/2^+$. But, the actual situation is even worse. The $g_{9/2}$ spectroscopic factor is almost certainly no larger than about 0.01–0.02, so the expected width for p_1 decay is $\Gamma_{calc} = S\Gamma_{sp} < 14$ eV. The $1/2^+$/g.s. BR, with my calculated ground-state width, is thus less than about 2×10^{-4}, to be compared with the recently reported value [1] of $0.19 = 0.16(7)/0.83(3)$ for this state. The present value is compared with others in Table IV. I can only conclude that the p_1 decays must be from a nearby state—perhaps the one at 7.37 MeV, about which little is known. The recent paper states that the authors did not observe this state, but it was seen in an earlier (^{3}He,n) study [8] with a cross section of about 3% of that for the ^{18}Ne(g.s.). Perhaps it is strong enough in the present experiment to account for the p_1 decays. Or, they might be from a previously unknown state in this region of excitation. Hahn *et al.* [8] reported two states near here—at 7.05 and 7.12 MeV.

If the peak attributed [1] to the decay ^{18}Ne(7.06 MeV) $\rightarrow$ ^{17}F($1/2^+$) arises instead from the decay of some other state to ^{17}F(g.s.), Almaraz-Calderon *et al.* [10] indicate that the excitation energy of this other state would be about 6.7 MeV—an energy corresponding to no known state in ^{18}Ne. As they state, this would "indicate the possibility of a new, previously unobserved state in ^{18}Ne." Clearly, more work is needed in this important region of ^{18}Ne.

I note that the new paper states that Harss *et al.* [4] assigned 2^+ to the 7.37-MeV state. But that was a suggestion, not an assignment. Harss *et al.* stated that their data are consistent with any natural-parity J^π, up to some high J. They suggested 2^+ simply because the lowest state of ^{18}O without an identified mirror was the 2^+ state at 8.21 MeV. I will not repeat the argument here, but we proved [6] that the 7.37-MeV state in ^{18}Ne is not the mirror of the 8.21-MeV state in ^{18}O. Mirrors of both states remain to be identified.

I note that, with our calculated alpha width of 22.6(3.2) eV for the 7.06-MeV state, our value of the relevant astrophysical strength parameter $\omega\gamma$ is only 0.56 of the one in common use.

TABLE I. Branching ratios from Ref. [1] for the 4_2^+ state of ^{18}Ne.

E_x (MeV)	J^π	p_0	p_1
7.06(4)	4^+	0.83(3)	0.16(7)

TABLE II. Wave functions from Ref. [7] for ^{18}O/^{18}Ne(4_2^+).

Configuration	Wave-function amplitude
d^2	0.120
dd'	−0.392
Coll.	0.912

TABLE III. Properties of the 4_2^+ state.

Quantity	Exp. [1, 4]	Calc.
E_x (MeV)	7.06(4)	7.086(40) [5]
Γ_α (eV)	39(13)	22.6(3.2) [6]
Γ_p (keV)	90(40)	64(13) [6]

TABLE IV. Reported branching ratios p_1/p_0 for ^{18}Ne(7.06 MeV, 4^+).

Source	Branching ratio
Harss *et al.* [4]	$\leqslant 1/90$
Notani *et al.* [9]	Large
Almaraz-Calderon *et al.* [1]	0.19
Present	2×10^{-4}

In summary, my calculated p_1/p_0 BR for the 7.06-MeV 4^+ state of ^{18}Ne is less than about 2×10^{-4}, in agreement with an earlier limit of $\leqslant 1/90$ from Harss *et al.* [4], but not with the value of 0.19 in a recent report [1]. The value from Notani *et al.* [9] is even larger. Finally, the "best" $\omega\gamma$ for this resonance is only 0.56 of the value in common use.

I am grateful to S. Almaraz-Calderon for informative correspondence.

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