Narrow 0^+ state in ^{20}Ne and the 0_6^+ and 0_7^+ rotational bands

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A reanalysis of old data removes the $(0^+,2^+)$ ambiguity for a very narrow state at $E_x(^{20}\text{Ne})=11.55$ MeV and gives a unique 0^+ assignment. Such a 0^+ state corresponds well to a predicted state at 11.494 MeV of unusually small reduced widths for decay to both the ground and first excited state of ^{16}O. This new 0^+ state is a better 0_6^+ band head for the 8p-4h states at 15.159 MeV (6^+) and 18.538 MeV (8^+) than the currently accepted 0^+ state at 12.44 MeV. Possible 2^+ and 4^+ members are considered. The higher 0^+ level at $E_x=12.44$ starts a new 0_7^+ band, and candidates for this band are critically discussed.

INTRODUCTION

Steck,[1] from a study of $^{16}\text{O}(\alpha,\gamma)^{20}\text{Ne}$ and from a phase shift analysis of $^{16}\text{O}(\alpha,\alpha_0)^{16}\text{O}$, found a narrow resonance at $E_x=11\,552\pm8$ keV for which he limited the possible spin assignments to 0^+ or 2^+. The ambiguity arose because the natural level width was enough less than his resolution that the folding in of the resolution removed most of the resonance's phase and amplitude interference effects. His analysis assumed $\Gamma_{\alpha_0}\approx\Gamma$, a reasonable assumption since the resonance is only $\sim$770 keV above the threshold for inelastic scattering to ^{16}O (6.05 MeV). With these assumptions Steck found $\Gamma=1.0\pm0.5$ keV. At Oxford, Fifield *et al.*[2] confirmed Steck's results and quoted $E_x=11\,557\pm6$ keV, $(0^+,2^+)$, $\Gamma=1.3\pm0.8$ keV based solely on the Oxford $^{16}\text{O}(\alpha,\gamma)^{20}\text{Ne}$ measurements. The fact that decay from radiative capture was 100% to the 2^+, ^{20}Ne (1.63 MeV) state perhaps favors a 0^+ assignment since the ground state decay $(0\rightarrow0)$ would be forbidden, but does not exclude a 2^+ assignment. According to Ref. 2 the corresponding $BM(\lambda)$ are 1.6 ± 0.2 W.u. for $E2$ $(J=0^+)$ and $(4.1\pm0.6)\times10^{-3}$ W.u. for $M1$ $(J=2^+)$. Fifield *et al.*[2] also assign $T=0$ to this state.

RESOLUTION OF THE $0^+,2^+$ AMBIGUITY

We have reanalyzed Steck's elastic scattering data[1] using a technique for spin zero particles which expands the scattering amplitude into resonant and nonresonant terms.[3,4] The nonresonant term can vary linearly with energy. If quality excitation data at many angles are available, this technique has been very successful in identifying the resonant l and hence J^π (for spin zero systems) of states whose width is small compared to the fitting interval.[3–6] Also, the strength for elastic scattering, Γ_{α_0}/Γ, is treated as a free resonant parameter.

Steck's excitation data are in 5-keV steps at 14 angles. Experimental resolution (chiefly energy straggling and target thickness) smears out any sharp resonances and greatly reduces the height of the resonant excursion.

While Steck folded these target and beam effects into his phase shift analysis and thus obtained an accurate level width $\Gamma=1.0\pm0.5$ keV, we chose to focus on the J^π assignment and let the program adjust Γ and Γ_{α_0}/Γ to fit the smeared-out data. The distinguishing signature between the 0^+ and 2^+ assignment will then be how well the program can fit at angles where $P_2(\cos\theta)$ differs strongly from $P_0(\cos\theta)$, e.g., for $\theta\cong125°$, where $P_2(\cos\theta)\cong0$.

We used Billen's program[4] to fit simultaneously at all 14 angles the elastic scattering data from Steck.[1] (The recent modifications of Billen's program by Caskey[7] and Riedhauser[8] were not needed for fitting this narrow region containing only one level.) Figure 1 shows for a few sample angles the best fits which could be achieved for both a 0^+ and a 2^+ assignment. Note that for angles *not* near $\theta=125°$ (where $P_2\cong0$) the two fits are nearly equivalent. However, at $\theta=119.0°$ and at $\theta=123.6°$ only the 0^+ assignment could fit the resonant excursion. The overall χ^2/degree of freedom for all 14 angles is 0.66 for the 0^+ and 0.92 for the 2^+ solution. This rather small difference of course largely reflects the fact that at angles not near $P_2(\cos\theta)=0$ the smeared-out fits are indistinguishable. The fitted parameters, $\Gamma_{\text{exp}}=10.2$ keV and the ratio $(\Gamma_{\alpha_0}/\Gamma)=0.12$, also largely reflect the energy-target smearing and only imply that $\Gamma\ll10.2$ keV and $\Gamma_{\alpha_0}/\Gamma\gg0.12$. (For a recent discussion of resolution effects on level parameters see Ref. 9.)

Since the fitting program permits the background amplitude and phase to vary linearly with energy, comparison of the resultant backgrounds and phases for the $l=0$ and 2 possibilities is also of interest. While the needed background amplitude variations were reasonable for both possibilities, the variation was less for the $l=0$ assumption. The fitted phase of the background was reasonable at all angles for an $l=0$ resonance, but for the $l=2$ choice, at one angle (66.8°) the background phase showed an oscillation over the resonance such as to reduce the $l=2$ resonance contribution. Hence, we conclude that the needed variations in background are consistent with our

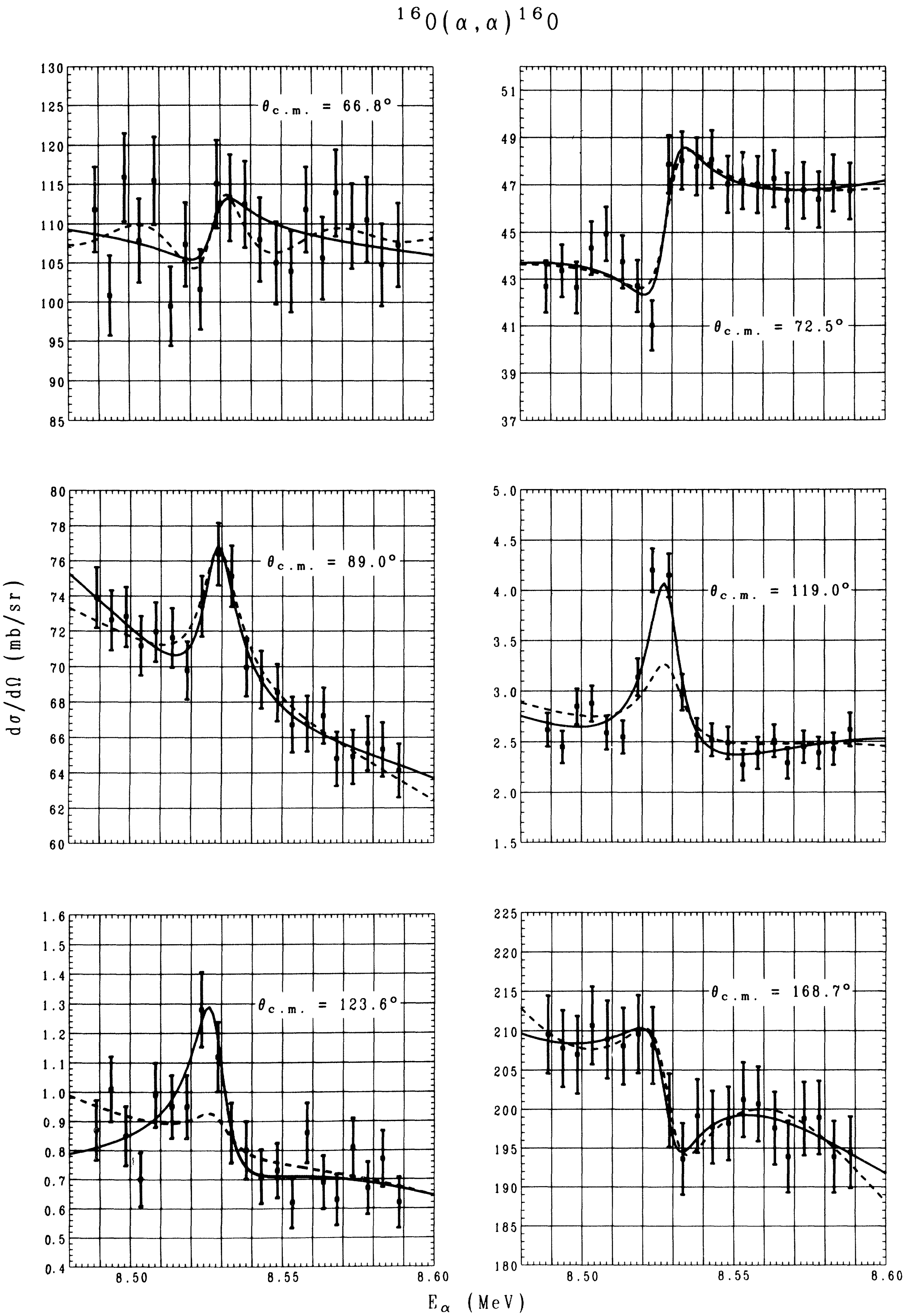

FIG. 1. Fits at sample angles to $^{16}O(\alpha,\alpha_0)$ data near $E_x=11.55$ MeV in ^{20}Ne ($E_\alpha=8.53$ MeV). The solid lines correspond to a 0^+ resonance and the dashed lines to a 2^+ resonance. The fitting program uses as scattering amplitude a resonant term and a nonresonant term which can vary linearly with energy. The $l=0$ and $l=2$ fits are equivalent at most angles, but at $\theta=119°$ and $\theta=123.6°$ [which are near $\theta=125°$ where $P_2(\cos\theta)=0$] only the 0^+ assignment is satisfactory.

$l=0$ choice.

Our new 0^+ level at 11.55 MeV may be the same as a tentative 0^+ state reported[10] in 1977 at 11.48 ± 0.06 MeV in the $^{18}O(^3He,n)^{20}Ne$ reaction.

0_6^+ ROTATIONAL BAND

The band head

Until now only six 0^+ states at $E_x \leq 12.436$ MeV were known,[11] and all have been assigned as heads of rotational bands,[11,12] although in this paper we question the band head assignment of the 0^+, 12.436 MeV state. Probably the 0^+, 11.55 MeV state also starts a rotational band.

What are the characteristics of this 0^+ state at 11.55 MeV which will serve as signatures for members of this band? Its narrow total width ($\Gamma \sim 1$ keV) at this excitation energy is most remarkable for a $T=0$, 0^+ state and implies a reduced width $\theta_{\alpha_0}^2$ for alpha decay to the ground state of ^{16}O of $<2\times10^{-4}$. This value is about an order of magnitude smaller than any other known 0^+ state in ^{20}Ne. The next larger one with $\theta_{\alpha_0}^2 \approx 10^{-3}$ is the well-studied 8p-4h state at 12.44 MeV.

Brown[13] has calculated reduced widths for alpha decays for the seven 0^+ states below $E_x(^{20}Ne)=15$ MeV which are predicted in the shell model using a model space containing four (for ^{16}O) and eight (for ^{20}Ne) particles outside a closed ^{12}C core.

Of the seven 0^+ states with $E_x<15$ MeV, Brown[13] predicts that three around 12 MeV should have small $\theta_{\alpha_0}^2$ (see our Table I). The two predicted at 11.66 and 12.705 MeV also have a large $\theta_{\alpha_1}^2$ to the first excited state of ^{16}O. Garman *et al.*[14] point out that either of these two corresponds well to the experimental properties of the 0^+, 12.44 MeV state which they studied in great detail, namely, small $\theta_{\alpha_0}^2$ but large $\theta_{\alpha_1}^2$. The other 0^+ state predicted at 11.494 MeV should have small θ^2 for both the ground and first excited state of ^{16}O and thus corresponds well both in predicted energy location and the predicted very small total width to our 0^+ state at 11.55 MeV. We therefore tentatively identify our 0^+ state at 11.55 MeV with the one Brown predicted at 11.494 MeV.

Recently, Hindi *et al.*,[15] via $^{12}C(^{12}C,\alpha)^{20}Ne$, reported an 8^+ state at 18.538 MeV which has large $^{12}C+{}^8Be$ clustering but very small $\theta_{\alpha_0}^2$. They therefore associated it with a new rotational band headed by the 0^+, 12.44 MeV state which Garman *et al.*[14] found to have a small $\theta_{\alpha_0}^2$. Hindi *et al.* included in the new band a 6^+ state at 15.159 MeV which also had a small $\theta_{\alpha_0}^2$, but they could not find convincing candidates for the 2^+ and 4^+ members.

Since the chief characteristic of the 0^+, 12.44 MeV state is not its small $\theta_{\alpha_0}^2$ but its huge $\theta_{\alpha_1}^2$ of ~ 1, any other member of a band based on it as a head should have very large $\theta_{\alpha_1}^2$. There is no evidence that either the 6^+ or 8^+ state proposed by Hindi *et al.*[15] has an appreciable $\theta_{\alpha_1}^2$. In fact, for the 6^+ state, Young *et al.*[16] find the decay is primarily via α_2 and α_3 and less than 4% to α_1. For the 8^+ state Hindi *et al.*[15] did not resolve α_1 from α_2 decay, nor α_3 from α_4, but did quote $\theta_{\alpha_{1+2}}^2=0.085\pm0.014$ on the assumption that α_2 dominates, and $\theta_{\alpha_{3+4}}^2=0.24$, assuming that α_3 dominates. This first assumption is consistent with the strong triple correlations ($\alpha_0\alpha_{1+2}\gamma$) which they see for decay to ^{16}O (6.13, 3^-). Unfortunately, in neither case are the data sufficiently good to exclude the fact that $\theta_{\alpha_1}^2$ may be appreciable since the lower centripetal barrier will favor α_2 over α_1. However, the barrier penetrabilities are not so different for α_3 and α_1. Hence, we question whether the 0^+, 12.44 MeV state belongs to the band pro-

TABLE I. Predictions by Brown (Ref. 13) of excitation energies and reduced widths for α-particle decays of 0^+ states in ^{20}Ne.

	$E_x(^{20}Ne)$ (MeV)	$\theta_{\alpha_0}^2$	$\theta_{\alpha_1}^2$	$\theta_{\alpha_1}^2/\theta_{\alpha_0}^2$
1	0.000	0.35	0.003	0.0088
2	7.093	0.054	0.02	0.37
3	8.494	0.012	0.15	12.6
4	11.494	0.0002	0.005	18.8
5	11.664	1×10^{-7}	0.029	245 000
6	12.705	0.0003	0.040	123
7	14.649	0.0009	0.0019	2.09

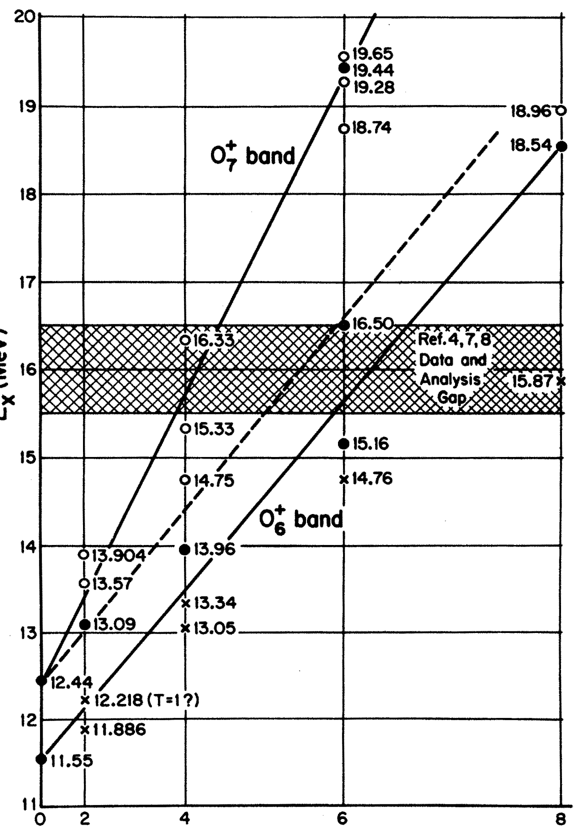

FIG. 2. E_x vs $J(J+1)$ plot for ^{20}Ne levels which might be candidates for the 0_6^+ and 0_7^+ rotational bands. The solid lines correspond to our preferred band slopes. The solid circles correspond to relatively well-established band members. The (x)'s indicate states which have some, but not all, of the characteristics expected of 0_6^+ band members. Open circles relate similarly to possible 0_7^+ band members.

TABLE II. ^{20}Ne states under consideration for the 0_6^+ band.

J^π	E_x (MeV±keV)	Γ (keV)	Γ_{α_0} (keV)	$\theta_{\alpha_0}^2 \times 10^3$	Ref.
0^+	{11.552±8	1.0±0.5		0.2[a]	1
	{11.557±6	1.3±0.8			2
2^+	11.866	46		11[a]	17
	{12.218±4[b]	<1		<0.2[a]	2
	{12.216±5[b]	<2			18
4^+	13.045±1	18±3	10±3	3.7±1.3	7
	{13.337±1	26±3	18±5	6.2±2	7
	{13.342±6	20	14	5	20
	13.962±1	10±2	4.5±1.5	1.4±0.5	7
6^+	14.757±5[c]	11[d]	2[d]	1.6[d]	7
	15.159±5	60±15[e]	1.2±1.5[f]	1±1.3[e,f]	15,16
	16.502±12	24±4	8.6±2.2	4±1	8
8^+	18.538±7	138±13	2.5±1.5	3.2±1.9	15

[a]Γ_{α_0} assumed $=\Gamma$.
[b]There is persuasive evidence that the state is $T=1$.
[c]Tentative J^π.
[d]Parameter not well fixed.
[e]From Ref. 15.
[f]Calculated with $\Gamma_{\alpha_0}/\Gamma=0.02\pm0.02$ from Ref. 16.

posed by Hindi *et al.*[15] Instead we suggest that the 0^+, 11.55 MeV state may have more characteristics in common with the proposed band of Hindi *et al.*[15] involving the 6^+ and 8^+ cluster states and so should replace the 0^+, 12.44 MeV state as band head. We note that when this is done, the 0_6^+ band members lie closer to a straight line on an E_x vs $J(J+1)$ band plot (see Fig. 2). The change in band head also gives a steeper slope which is more physically plausible than that of the Hindi *et al.*[15] choice since the latter requires a moment of inertia of 6.0 $(\text{MeV})^{-1}$, whereas two touching spheres of ^{8}Be and ^{12}C give only 5.8 $(\text{MeV})^{-1}$.

There remain the problems of identifying the 2^+ and 4^+ members of the 0_6^+ band and locating candidates for a new 0_7^+ band built on the higher 0^+, 12.44 MeV state, which has (theoretically and experimentally) a very small $\theta_{\text{g.s.}}^2$ but very large $\theta_{\alpha_1}^2$.

In the following discussions we have supplemented the ^{20}Ne level information from the Ref. 11 compilation with recent $^{16}\text{O}(\alpha,\alpha_i)^{16}\text{O}$ data and analyses from Caskey[7] and Riedhauser.[8] Tables II and III list levels which might be considered for the two bands.

Other members of the 0_6^+ band

In the literature[11] only a couple of 2^+ states have $E_x \sim 12$ MeV as expected for the proposed 0_6^+ band. One at 11.886 MeV, reported[17] in the $^{16}\text{O}(\alpha,\alpha_0)$ reaction, has a reduced width (if $\Gamma_{\alpha_0}\sim\Gamma$) of $\theta_{\text{g.s.}}^2=11\times10^{-3}$ which is much too large for this band. The other possibility is a 2^+ state at 12.218 MeV, seen[2,18] in $^{16}\text{O}(\alpha,\gamma)^{20}\text{Ne}$, which has an undetected Γ_{α_0} and Γ_{α_1} and a total $\Gamma<1$ keV, and so the reduced widths are certainly small enough. A fatal objection to it being a band member is the quite persuasive evidence[2,18] that it is a $T=1$ state corresponding to the 2^+ state in ^{20}F at 2.04 MeV.

That no $T=0$, 2^+ state of suitably small $\theta_{\alpha_0}^2$ has been reported is understandable because no $^{16}\text{O}(\alpha,\alpha_0)$ data of requisite resolution exist for this energy region. Also, the heavy-ion reactions used to discover the 6^+ and 8^+ members are relatively insensitive to low spin states in an excitation region where the level density is appreciable. Thus, above 12 MeV, the only low spin ^{20}Ne state ever identified via $^{12}\text{C}(^{12}\text{C},\alpha)^{20}\text{Ne}$ was the 0^+, 12.44 MeV state reported first[17] by $^{16}\text{O}(\alpha,\alpha_0)$ and which Balamuth *et al.*[19] only saw by (α,γ) coincidence with annihilation radiation from the abnormally large branch to the ^{16}O (6.05 MeV) pair emitting state.

A search of current literature for a possible 4^+ band member reveals only three candidates which have about the right energies and moderately small $\theta_{\alpha_0}^2$ (see Table II). The one with smallest $\theta_{\alpha_0}^2$ $(=1.4\times10^{-3})$ at 13.962 MeV is a new narrow state seen by Caskey,[7] but the energy is somewhat high. The 13.342 MeV state reported by Häusser *et al.*[20] in $^{16}\text{O}(\alpha,\alpha_0)$ scattering has the right energy although its $\theta_{\alpha_0}^2$ $(=6.2\pm2\times10^{-3}$ as measured by Caskey[7]) is on the high side. Hindi *et al.*[15] suggested this state as a candidate for their new band. The third 4^+ candidate at 13.045 MeV $(\theta_{\alpha_0}^2=3.7\pm1.3\times10^{-3})$ is another new state,[7] but its energy is somewhat low. Thus there is no clear choice and, in fact, the 4^+ member may as yet be

TABLE III. ^{20}Ne states to be considered for the 0_7^+ band.

J^π	E_x (MeV±keV)	Γ (keV)	Γ_{α_0} (keV)	Γ_{α_1} (keV)	$\theta^2_{\alpha_0}\times 10^3$	$\theta^2_{\alpha_1}\times 10^2$	Ref.
0^+	{12.436±4	24.4±0.5	3.6±0.9	20.8±0.4	0.6±0.2[a]	210±4[a]	14
	{12.430±4	29±13	18±12	11±25[b]	3±2	90±90[b]	7
2^+	{13.096[c]	39[c]	5[c]	≤34[c]	1[c]	≤100[c]	7
	{13.09[c]			large			22
	13.570±2	12±5	2.3±1.7	≤10±5	0.43±0.3	≤8±4	7
	{13.904	50	31	19	5.5	7.7[a]	23
	{13.905	74±10	56±12	≤18±16	9.8±2.1	≤7±6	7
4^+	{13.962±1	10±2	4.5±1.5	≤6±3	1.4±0.5	≤40±30	7
	{13.99			d			22
	{14.724±15[e]	59[e]	14[e]	≤45[e]	3.3[e]	≤60[e]	7
	{14.75[e]			d			22
	15.327±5	21±11	6±4	≤15±12	1.9±1.4	≤8±6	7
	16.325	43	f	f			3
6^+	16.502±12	24±4	8.6±2.2	≤16±5[g]	4±1	≤42±13[g]	8,4
	18.742±24	141±46	24±11	≤117±47[g]	6±3	≤32±13[g]	8
	19.281±13	137±32	h	16.4±7[i]		j	8,4
	19.440±9	131±13	h	50±6[i]		j	8,4
	19.652±18	139±35	h	19.5±8[i]		j	8,4
	20.442±25	366±54	30±18[k]	≤336±72[k]	6±4[k]	≤33±7[k]	8,4

[a]Recomputed by us for $r_0=1.25$ fm.
[b]Assuming $\Gamma=\Gamma_{\alpha_0}+\Gamma_{\alpha_1}$.
[c]Tentative (2^+) and parameters not well determined.
[d]Seen only in the (α,α_1) channel.
[e]Tentative (4^+) and parameters not well determined.
[f]Resonance seen by Ref. 3 both in α_0 and α_{1+2} channels but no (α,α_1) resonance seen by Ref. 22.
[g]No strong (α,α_1) resonance seen by Ref. 22.
[h]Not seen in the (α,α_0) channel.
[i]Value is not Γ_{α_1}, but is $(\Gamma_{\alpha_0}\Gamma_{\alpha_1})^{1/2}$ from Ref. 8.
[j]Value is large, see the text.
[k]Assuming this state is the same as the elastic resonance at 20.416±31 MeV (±keV).

unobserved for the same reason as discussed for the 2^+ state.

While we have assumed the 6^+ and 8^+ band members as given by Hindi *et al.*[15], Table II (see also Fig. 2) shows that there are two other 6^+ possibilities. The proper choice is not obvious. In fact, the most likely band slope (see Fig. 2) suggests that the appropriate narrow 6^+ state may well exist undiscovered in the poorly studied region between the data of Caskey[7] and Billen.[4] In connection with the 6^+ level at 16.502 MeV, we note that long ago Gorodetzky *et al.*[21] reported preliminary measurements of ^{19}F(p,^{8}Be)^{12}C and ^{16}O(α,^{8}Be)^{12}C for E_x(^{20}Ne) betwen 15.3 and 18.7 MeV. They claimed some dozen resonances. The one at 16.50 MeV had $\Gamma_{\alpha_0}=2$ keV, $\Gamma_{\alpha_1}=21$ keV, and $\Gamma_{^8\mathrm{Be}}=45$ keV; hence, it would have some of the properties we desire for a 6^+ member of either the 0_6^+ or 0_7^+ band (see below) except that the preliminary Brief Report lists the J^π as 3^-. (No basis is given as to how reliable the assignment is.)

THE NEW 0_7^+ BAND

Since the 0_7^+ state at 12.44 MeV has[14] a very small $\theta^2_{\alpha_0}$ ($\sim 10^{-3}$) and a very large $\theta^2_{\alpha_1}$ ($=\sim 1$), we look for these characteristics in possible band members.

Of the many known 2^+ levels with $12.5 < E_x < 14.5$ MeV only three show promise. One level is a strong ^{16}O(α,α_1) resonance at 13.09 MeV reported as a tentative (2^+) by Garman[22] in her unpublished 1980 Ph.D. thesis at Oxford University. The Γ_{α_0} is presumably small because Caskey[7] via ^{16}O(α,α_0) reports no 2^+ at this energy. However, Caskey had poor data fits in this region, but χ^2 dropped by 11% when he added a very weak (0^+) level. Very recently, he found an equivalent improvement in χ^2 by replacing the tentative 0^+ state with a 2^+ level. The resultant parameters (if 2^+) give a $\theta^2_{\alpha_0}\sim 10^{-3}$ and $\theta^2_{\alpha_1}\leq 1$.

The second possibility is the narrow 2^+, 13.570 MeV state for which Caskey calculated a very suitable $\theta^2_{\alpha_0}=4.3\times 10^{-4}$. However, the corresponding limit on $\theta^2_{\alpha_1}$ of ≤ 0.08 is consistent with Garman[22] seeing no (α,α_1) resonance and would seem to exclude this state from further consideration.

The third possibility is the 2^+, 13.904 MeV state for which Isoya[23] from ^{19}F(p,α_0) and ^{19}F(p,α_1) data calculated $\theta^2_{\alpha_0}=5.5\times 10^{-3}$ and $\theta^2_{\alpha_1}=36\times 10^{-3}$. For the same state Caskey,[7] via ^{16}O(α,α_0), finds an even higher $\theta^2_{\alpha_0}=9.8\times 10^{-3}$ and limits $\theta^2_{\alpha_1}$ to $<70\times 10^{-3}$, so this state also seems excluded because of the too small $\theta^2_{\alpha_1}$.

The present data therefore strongly favor the state at 13.09 MeV for the 2^+ member and hence a band slope like the 0_6^+ band (see the dotted line in Fig. 2).

While Table III indicates that several 4^+ states have suitable $\theta^2_{\alpha_0}$, the tentative 4^+, 15.327 MeV level can probably be excluded on the basis of Caskey's limit of $\theta^2_{\alpha_1} \leq 0.08$. Also, the 4^+, 16.33 MeV state reported by Hausser *et al.*[3] is an unlikely choice since Garman[22] sees very little (α,α_1) strength in this region. Caskey's new narrow 4^+ level at 13.962 MeV has satisfactory values for both reduced widths and undoubtedly corresponds to the 4^+ which Garman reported at 13.99 MeV from (α,α_1). Likewise, Caskey via (α,α_0) and Garman via (α,α_1) each identify a tentative 4^+ state near 14.74 MeV which would be acceptable.

While either of the latter two may qualify as the 4^+ member of the 0_7^+ band, consideration of possible 6^+ candidates (see below) suggests that the 0_7^+ band may have a steeper slope (the solid line of Fig. 2). If so, the 4^+ band member may well lie undiscovered in the gap, poorly studied by (α,α_0), between the work of Caskey[7] and Billen.[4] In fact, Garman's[22] unpublished (α,α_1) thesis study of this region does show several very strong (overlapping) resonances at $\theta = 54.7°$ which disappear at $\theta = 70.1°$ where $P_4(\cos\theta) \simeq 0$. However, most of the resonances also disappear at $\theta = 90°$, which implies odd parity or strong accidental cancellations.

Possible higher J candidates for the 0_7^+ band

We come next to 6^+ candidates for the 0_7^+ band. Billen[4] and Riedhauser[8] agree on a narrow 6^+, 16.502 level with $\theta^2_{\alpha_0} \sim 4 \pm 1 \times 10^{-3}$. Examination of Billen's unresolved $\alpha_1 + \alpha_2$ data and also his α_3 and α_4 data (see Figs. 5—10 of Ref. 4) shows that the same resonance appears in these channels. This state lies nicely along a possible low slope band, but Garman[22] reports no strong (α,α_1) resonance, so it is an unlikely member.

No other very promising 6^+ candidate appears until one gets to $E_x \sim 19.4$ MeV where Billen[4] found a remarkably strong α_1 yield (see $\sigma_T = 4\pi\, a_0$ in his Fig. 15 and the a_{12} Legendre coefficient in his Fig. 16). Fitting of the actual data (e.g., his Fig. 30) required four overlapping 6^+ levels (Billen's Table III). Riedhauser's reanalysis[8] of the data confirms the results and gives better parameters. Riedhauser[8] also succeeded in analyzing the simultaneously taken α_0 data and found little correspondence (with one exception) of the α_0 resonances to the four α_1 resonances. Hence, three of this cluster of 6^+ states, strongly decaying in the α_1 channel and very weakly in the α_0 channel have the same characteristics as the band head. (These overlapping 6^+ states should mix strongly.)

We therefore choose the 19.44 MeV level as the most likely 6^+ candidate, since it is near the center of the overlapping cluster and has the highest $(\Gamma_{\alpha_0}\Gamma_{\alpha_1})^{1/2}$ value. However, at even higher excitation energies several other 6^+ levels occur in the α_1 channel. Riedhauser[8] finds a 20.442 MeV level with a huge $(\Gamma_{\alpha_0}\Gamma_{\alpha_1})^{1/2} = 117$ keV; if this state is the same as the elastic resonance he sees at 20.416 MeV, then $\theta^2_{\alpha_0} = 6 \pm 4 \times 10^{-3}$ and $\theta^2_{\alpha_1} \leq 0.33$.

An 8^+ candidate?

Billen's data[4] ($19 < E_x < 21$ MeV) had no indication of any 8^+ strength in the α_1 channel. In the α_0 channel Riedhauser[8] reports an 8^+, 18.957 MeV state with $(\theta^2_{\alpha_0} = 0.03)$. However, there is no evidence for appreciable α_1 yield, and the ground state reduced width is too large. This level may belong to the 0_5^+ band.[12] The lack of any suitable 8^+ candidate below 21 MeV also argues against the lower slope (the dotted line in Fig. 2) for the 0_7^+ band. The more likely band slope (the solid line in Fig. 2) gives an extrapolated 8^+ location ~ 24 MeV. Unfortunately, nothing is known about the Γ_{α_1} and Γ_{α_0} of any of the 8^+ levels above $E_x = 21$ MeV, so even speculation about an 8^+ candidate for a possible high slope band is presently not productive.

CONCLUSIONS

In summary, we have been able to assign 0^+ to a state in ^{20}Ne at 11.55 MeV which has unusually small width for alpha decay. We suggest that this 11.55 MeV state is a more appropriate 0_6^+ head for a recently suggested band involving 6^+ and 8^+ members with large cluster configurations than an earlier suggested 0^+ state at 12.44 MeV. We discuss candidates for the 2^+ and 4^+ members of the 0_6^+ band. A new 0_7^+ band based on characteristics of the 0^+, 12.44 MeV state is explored. Possible members seem to lie either on a low slope line paralleling the 0_6^+ band or, more likely, on a high slope line like the 0_1^+ band. Decisions on band members will need both better experimental information and better theoretical calculations of the properties of the band members.

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