Energy Levels in B^{10} in the Reaction $Li^6(\alpha,\gamma)B^{10}$†

LUISE MEYER-SCHÜTZMEISTER AND S. S. HANNA
Argonne National Laboratory, Lemont, Illinois
(Received August 22, 1957)

The yield of the reaction $Li^6(\alpha,\gamma)B^{10}$ was measured as a function of bombarding energy from 0.7 up to 3.8 Mev. Five levels in B^{10} were found at excitation energies of 4.77, 5.11, 5.16, 5.91, and 6.02 Mev. Only the levels at 4.77 and 5.16 Mev have been observed previously in this reaction. Resonance widths, cross sections, branching ratios, and angular distributions are given for the levels. Spin assignments of 2^+ (or possibly 3^+) to the 4.77-Mev level and 4^+ to the 6.02-Mev level are indicated by the evidence. For the other levels many spins are ruled out but definite assignments cannot be given.

INTRODUCTION

ENERGY levels in B^{10} above 4.4 Mev may be investigated with the simple capture process $Li^6(\alpha,\gamma)B^{10}$. An (α,γ) reaction is attractive for study because of the lack of spin of the alpha particle and the relatively well understood features of the electromagnetic radiation. Earlier investigations[1] of this reaction have covered only a limited range of excitation energies.[2] Considerable theoretical interest is attached to the levels in B^{10} in this region, especially since the assignments which have been suggested by the experimental work are not fully compatible with expectation.[3]

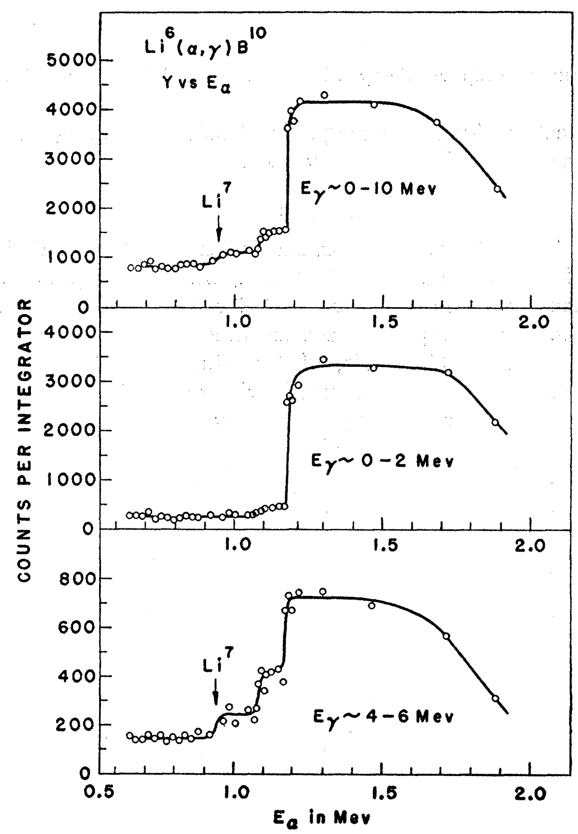

FIG. 1. Thick-target yield curves in the reaction $Li^6(\alpha,\gamma)B^{10}$.

EXPERIMENTAL ARRANGEMENT

The beam of alpha particles was supplied by the 4.0-Mev electrostatic generator in the Argonne physics division. After analysis in a 90° electrostatic analyzer with radius of curvature equal to one meter, the beam impinged on a rotating target of Li^6 metal. The rotating unit was a standard assembly used in this laboratory in the production of fast neutrons. The Li^6 metal[4] was evaporated onto a 0.5-mil nickel foil mounted in a thin aluminum cup which produced negligible absorption.

The capture gamma rays were detected with a NaI crystal 3.5 inches in diameter and 3.5 inches long; the pulses were recorded in either a 10-channel or a 256-channel analyzer. The crystal was shielded by a lead jacket and mounted on an arm which could rotate about the target spot. The pivot was aligned by ob-

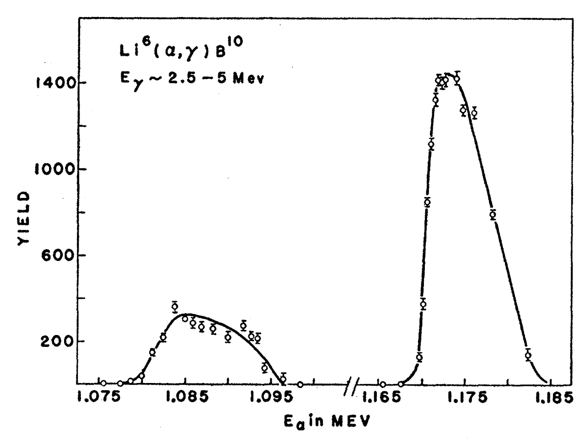

FIG. 2. Thin-target yield curve in the reaction $Li^6(\alpha,\gamma)B^{10}$. $E_\alpha = 1.075$–1.185 Mev.

† This work was performed under the auspices of the U. S. Atomic Energy Commission.

[1] D. H. Wilkinson and G. A. Jones, Phys. Rev. **91**, 1575 (1953); G. A. Jones and D. H. Wilkinson, Phil. Mag. **45**, 703 (1954).

[2] A summary is given in F. Ajzenberg and T. Lauritsen, Revs. Modern Phys. **27**, 77 (1955).

[3] A comparison on the basis of intermediate coupling is made by D. Kurath, Phys. Rev. **101**, 216 (1956).

[4] The sample contained 99.3% Li^6 and was supplied by the Stable Isotope Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

serving the reaction $F^{19}(p,\alpha\gamma)O^{16}$ with $E_p=0.935$ Mev, for which the angular distribution is known to be isotropic.[5]

EXCITATION FUNCTIONS AND SPECTRA

The energy region between $E_\alpha=0.7$ and 3.8 Mev was investigated with both thin and thick targets. Figure 1 shows yield curves obtained with thick targets with the 10-channel analyzer. The yield below $E_\alpha=0.9$ Mev is attributed to the resonance in $Li^6(\alpha,\gamma)B^{10}$ at $E_\alpha=0.50$ Mev. The rise at 0.95 Mev is due to a strong resonance in $Li^7(\alpha,\gamma)B^{11}$, which appears despite the small amount of Li^7 in the target. The steps at 1.09 and 1.18 Mev are from capture in Li^6. The resonance at 1.09 Mev has not been observed before,[1] although the corresponding state at 5.11 Mev in B^{10} is well known.[6,7] A curve showing this resonance for a thin target is reproduced in Fig. 2.

A careful search of the region from $E_\alpha=1.2$ to 3.8 Mev is illustrated in Fig. 3. Only two resonances, at 2.43 and 2.61 Mev, are found, although six states in B^{10} have been reported in this region.[6,7] Above $E_\alpha=2.2$ Mev the background rises slowly and culminates in broad structure at 3.3 Mev. This yield appears because the crystal responds to neutrons from the reaction $C^{13}(\alpha,n)O^{16}$ associated with the carbon contaminating the target. Identification of this reaction was made with targets having heavy carbon deposits. Several broad resonances observed agreed well with the expected structure[8] from $C^{13}(\alpha,n)O^{16}$. Moreover there were no peaks in the pulse-height spectra at these resonances which could be attributed to gamma rays. The more or less exponential character of the spectra was considered indicative of a complex response of the crystal to neutrons.

The gamma-ray spectrum was recorded at each resonance with the 256-channel analyzer. The results are reproduced in Figs. 4–8. A summary of all the measurements is given in Table I and an energy level diagram in Fig. 9. The total widths Γ listed in the table were obtained from measurements with both thick and thin

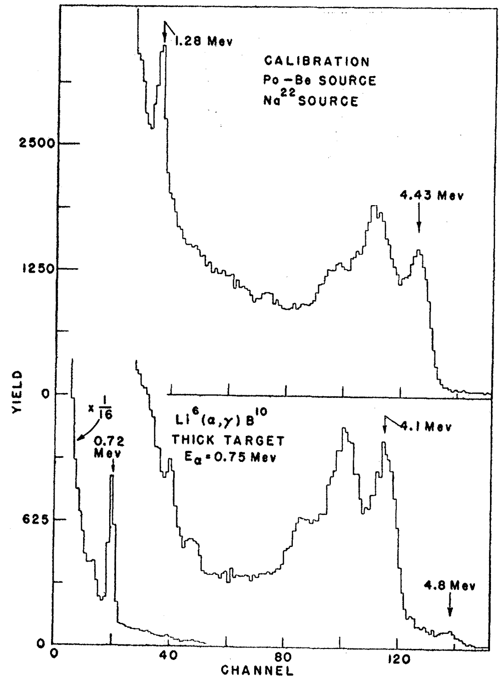

FIG. 4. Gamma-ray spectrum obtained with the 256-channel analyzer in the decay of the 4.77-Mev level in B^{10}. A thick Li^6 target was used with $E_\alpha=0.75$ Mev. For comparison is shown the gamma-ray spectrum of a Po-Be source (4.43 Mev) and a Na^{22} source (1.28 Mev) taken together.

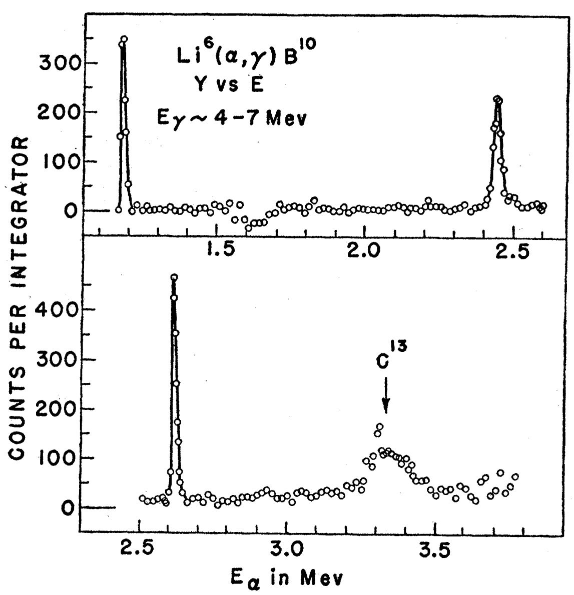

FIG. 3. Thin-target yield curve in the reaction $Li^6(\alpha,\gamma)B^{10}$. $E_\alpha=1.16$–3.8 Mev.

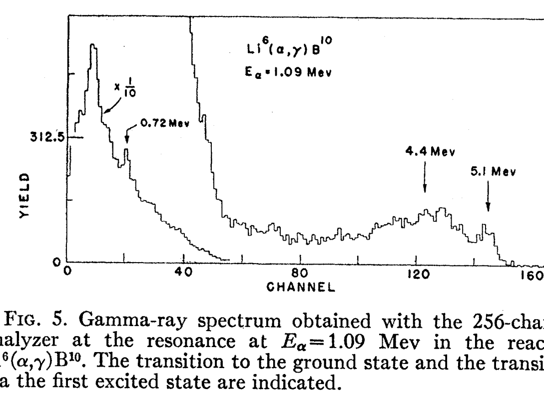

FIG. 5. Gamma-ray spectrum obtained with the 256-channel analyzer at the resonance at $E_\alpha=1.09$ Mev in the reaction $Li^6(\alpha,\gamma)B^{10}$. The transition to the ground state and the transition via the first excited state are indicated.

[5] Day, Chao, Fowler, and Perry, Phys. Rev. **80**, 131 (1950); J. E. Sanders, Phil. Mag. **44**, 1302 (1953).
[6] F. Ajzenberg, Phys. Rev. **88**, 298 (1952).
[7] T. W. Bonner and C. F. Cook, Phys. Rev. **96**, 122 (1954).
[8] G. A. Jones and D. H. Wilkinson, Proc. Phys. Soc. (London) **A66**, 1176 (1953); R. E. Trumble, Phys. Rev. **94**, 748(A) (1954); Bonner, Kraus, Marion, and Schiffer, Phys. Rev. **102**, 1348 (1956).

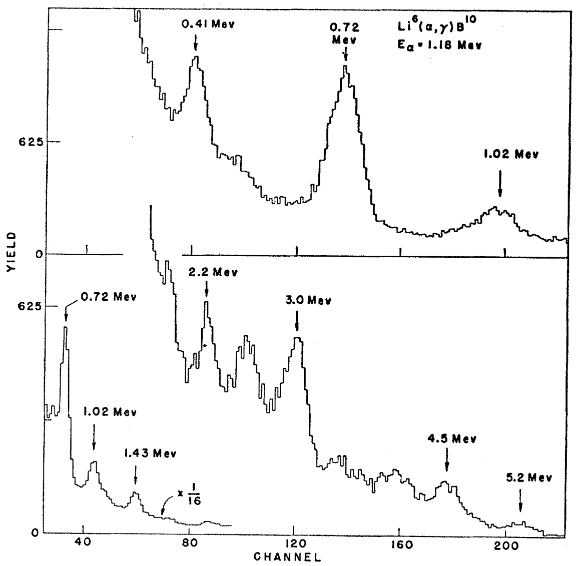

FIG. 6. Gamma-ray spectrum obtained with the 256-channel analyzer at the resonance at $E_\alpha=1.18$ Mev in the reaction $Li^6(\alpha,\gamma)B^{10}$. The transition to the ground state and the transitions via the first and third excited states are indicated.

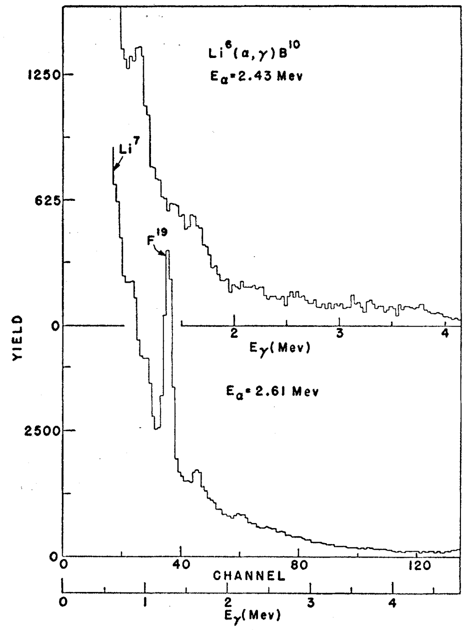

FIG. 8. Spectra of low-energy gamma rays (0.5 Mev $\lesssim E_\gamma \lesssim$ 4.5 Mev) obtained with the 256-channel analyzer at the resonances at $E_\alpha=2.43$ and 2.61 Mev in the reaction $Li^6(\alpha,\gamma)B^{10}$. The arrows indicate γ rays produced by the impurities Li^7 and F^{19}.

targets. The cross sections, expressed in the form $\omega\gamma = \pi\sigma_R\Gamma/\lambda^2 = 2\epsilon Y/\lambda^2$, were deduced from the thick-target yield curves. In this expression σ_R is the cross section at resonance, λ the wavelength of the alpha particle, ϵ the stopping power of the target for the alpha beam, and Y the thick-target yield.

ANGULAR DISTRIBUTIONS

In most cases the angular distributions were measured in a straightforward manner. At the two higher resonances it was necessary to correct for the background from the reaction $C^{13}(\alpha,n)O^{16}$ by taking runs alternately on and then just off resonance and using the off-resonance yield as the correction for background. At the lower resonances, only a "room" background had to be subtracted from the measurements. For the resonance at 1.18 Mev it was necessary to disentangle the gamma rays in the spectrum (see Fig. 6) in order to obtain results for individual gamma rays. As it turns out, the 4.44- and the 3.01-Mev gamma rays have very similar distributions and the 5.16-Mev radiation is very weak so that the results are not seriously affected by the incomplete resolution in the spectrum. A thick target was used to measure the angular distributions at the lowest resonance, since the Van de Graaff generator would not operate efficiently at 0.50 Mev. The angular distributions are plotted in Figs. 10–12 and summarized in Table II.

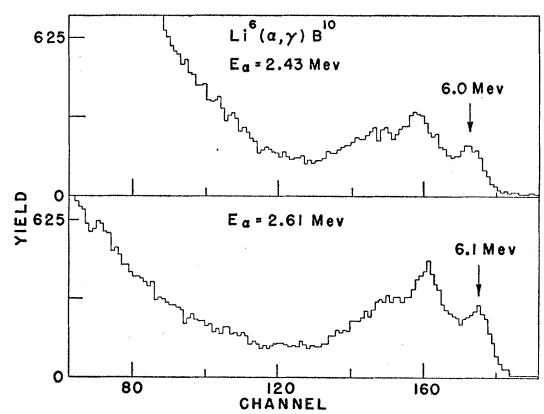

FIG. 7. Spectra of high-energy gamma rays ($E_\gamma \gtrsim 2.5$ Mev) obtained with the 256-channel analyzer at the resonances at $E_\alpha=2.43$ and 2.61 Mev in the reaction $Li^6(\alpha,\gamma)B^{10}$.

TABLE I. Resonances and gamma rays observed in $Li^6(\alpha,\gamma)B^{10}$. The cross section is expressed in the form $\omega\gamma=\pi\sigma_R\Gamma/\lambda^2$. The average error in Γ and in $\omega\gamma$ is about 25%.

			Primary radiation			Secondary
E_α (Mev)	E_{ex} (Mev)	Γ (lab) (kev)	E_γ (Mev)	(%)	$\omega\gamma$ (c.m.) (ev)	radiation (Mev)
0.50[a]	4.77[a]		4.77	8		
			4.05	92		0.72
1.085	5.105	7	5.105	96	0.10	
			4.39	4	0.005	0.72
1.175	5.16	3	5.16	7	0.04	
			4.44	29	0.15	0.72
			3.01	64	0.32	2.15; 1.43, 0.72; 0.41, 1.02, 0.72
2.435	5.91	20	5.91	100		
2.605	6.02	5	6.02	100		

[a] These values are taken from the literature.

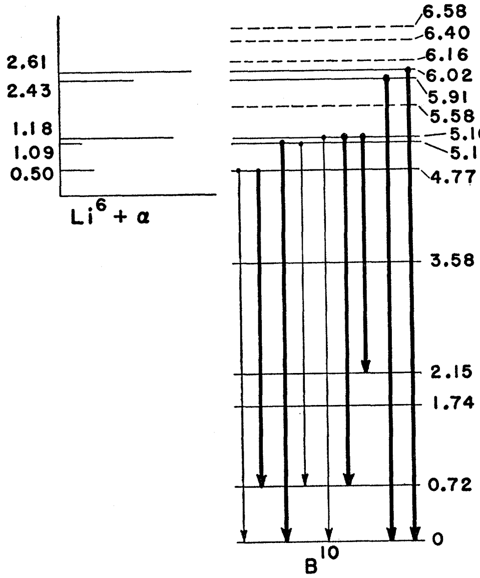

FIG. 9. Energy levels of B^{10}. The thick and the thin arrows indicate strong and weak transitions, respectively. All energies are in Mev.

THEORETICAL DISCUSSION

Theoretical angular distributions were calculated for all spin assignments up to three or four for each resonance. It is assumed throughout that there is no interference among these sharp well-separated resonances. The distributions are unique, therefore, if the angular momenta l_α and l_γ are unique. Otherwise, it is necessary to compute the angular distribution coefficients as functions of the parameters α_α, $\cos\xi_\alpha$, α_γ, and $\cos\xi_\gamma = \pm 1$, where α_α is the ratio of amplitudes and ξ_α the phase difference of alpha-particle waves corresponding to $(l_\alpha+2)$ and l_α, and similarly α_γ and ξ_γ denote the ratio and the phase difference for the mixed gamma-ray multipoles of order $(l_\gamma+1)$ and l_γ.

The result for a case in which l_γ is unique but l_α is not is depicted in Fig. 13. The shaded portion labeled "Theor" represents all allowed values of the angular distribution coefficient A_2 obtained when $\cos\xi_\alpha$ ranges from -1 to $+1$. In this particular instance, the experimental value -0.35 ± 0.07, at the resonance $E_\alpha = 1.09$ Mev, is incompatible with the theoretical possibilities, and the proposed scheme can be rejected (see Table III).

At each resonance each spin assignment was investigated in this manner and accepted or rejected on the basis of angular distributions, as summarized in Table III. Of those assignments not rejected, some are more likely than others because of their observed intensities.

4.77-Mev level.—Since the transition is primarily to the first excited state with $I = 1^+$, we consider spin assignments of 4 or more as being quite unreasonable. Of the two possible assignments in the table, 3^+ is improbable since a fit to the observed angular distribution is achieved only if the incident waves with $l_\alpha = 4$ and 2 have about equal intensities, which is quite unlikely

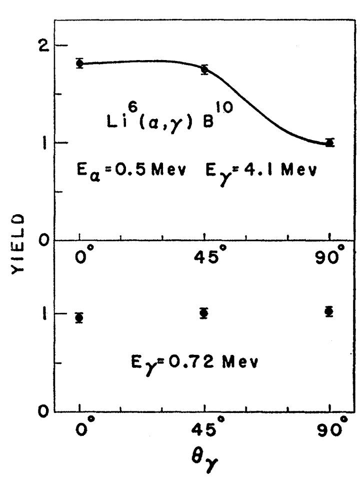

FIG. 10. Angular distributions of the 4.1- and the 0.72-Mev gamma rays which are emitted in succession from the 4.77-Mev level in B^{10}. The solid curve represents the best fitting theoretical angular distribution for the 4.1-Mev gamma ray, assuming the spin 2^+ for the 4.77-Mev level in B^{10}. The theoretical curve has been modified to take account of the solid angle.

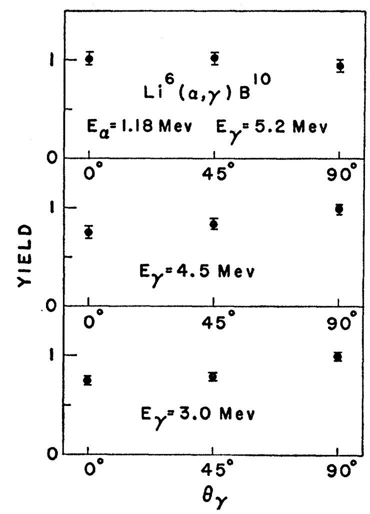

FIG. 11. Angular distributions of the 5.2-, 4.5-, and 3.0-Mev gamma rays which are emitted from the 5.16-Mev level in B^{10}.

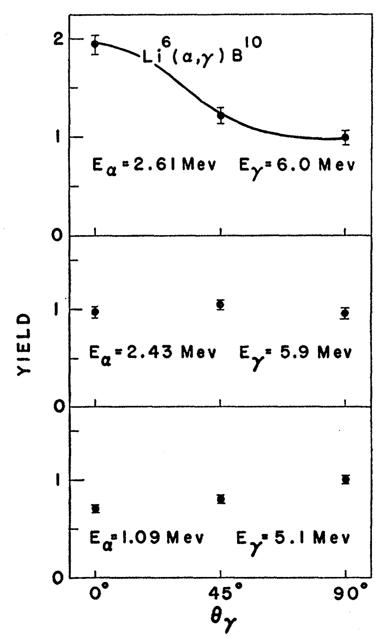

FIG. 12. Angular distributions of the 6.0-, 5.9-, and 5.1-Mev gamma rays emitted by the 6.0-, 5.9-, and 5.1-Mev levels in B^{10}, respectively. The solid curve represents the best fitting theoretical angular distribution for the 6.0-Mev gamma ray, assuming the spin 4^+ for the 6.0-Mev level. The theoretical curve has been modified to take account of the solid angle.

TABLE II. Observed coefficients in the expression $1+A_2\cos^2\theta+A_4\cos^4\theta$ for the angular distributions from the reaction $Li^6(\alpha,\gamma)B^{10}$. A value of A_4 is given only in those cases in which it seems statistically significant. Values corrected for the finite solid angle are listed in the last two columns. The error in each coefficient is approximately ±0.1.

Level in B^{10} (Mev)	E_γ (Mev)	Measured A_2	Measured A_4	Corrected A_2	Corrected A_4
4.77	4.05	2.2	−1.4	4.4	−3.4
	0.72	−0.05	···	−0.06	···
5.11	5.11	−0.30	···	−0.35	···
5.16	5.16	0.05	···	0.06	···
	4.44	−0.20	···	−0.25	···
	3.01	−0.20	···	−0.25	···
5.01	5.91	0.00	···	0.00	···
6.02	6.02	−0.10	1.05	−0.80	2.0

since the relative penetrabilities are in the ratio $1:10^4$. For the other possible assignment 2^+, the complete sequence of quantum numbers for the reaction is $1^+(2)2^+(1,2)1^+$. An $E2:M1$ ratio of 1.8 gives excellent agreement with the experimental distribution. The theoretical curve is drawn in Fig. 10. We consider 2^+ as the most probable assignment to this level.

5.11-Mev level.—All assignments up to 4^- are investigated; 4^+ is not considered because it requires $l_\alpha=4$. For 2^+ the complete scheme is $1^+(2)2^+(1,2)3^+$ and a good fit to experiment is attained with an $E2:M1$ ratio of 0.06 (or ∞). For 3^+ we have $1^+(2,4)3^+(1,2)3^+$. Only with $\alpha_\alpha^2=I_\alpha(4)/I_\alpha(2)\simeq 1$ is it possible to obtain even fair agreement with the experimental curve. About the best result is achieved when $\alpha_\alpha=1.0$, $\cos\xi=1$, $\alpha_\gamma=-0.9$, for which case $A_2=-0.21$ and $A_4=-0.16$. Not only are these latter values rather unsatisfactory but α_α is unreasonably large. The situation for 2^- is illustrated in Fig. 13. Unless the experimental result is seriously in error for this relatively weak resonance, 2^- must be eliminated from consideration. On the other hand, the assignment 4^- is a possibility. For $\alpha_\alpha=0$, one finds a value of $A_2=-0.44$ and for $\alpha_\alpha=1$, $\cos\xi_\alpha=+1$, the value becomes −0.39, as compared to the experimental result of −0.35.

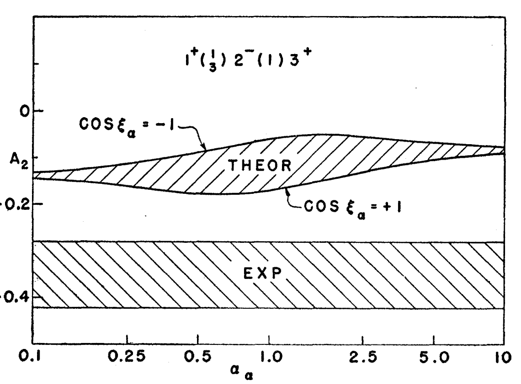

FIG. 13. The coefficient A_2 as a function of the parameters α_α and $\cos\xi_\alpha$. Theor: Shaded area represents all allowed values of A_2 calculated for the scheme $1^+(1,3)2^-(1)3^+$. Exp: Shaded area represents the range of allowed values corresponding to the experimental result corrected for the solid angle; i.e., to $A_2=-0.35\pm0.07$.

5.16-Mev level.—Since the transitions are chiefly to states with $I=1^+$, we again consider only assignments of 3 or less. For both 1^+ and 2^+, there is good agreement for all gamma rays if the parameters are suitably chosen. In the former case a value of $A_2=0.06$ can be obtained for the transition to the ground state if $I_\alpha(2)/I_\alpha(0)$ satisfies the condition in the table. For the transitions to the excited states, a value $A_2=-0.25$ is possible for a wide range of this parameter because of the possible variation in the parameter $I_\gamma(2)/I_\gamma(1)$. All transitions must correspond, of course, to some unique choice of α_α (and $\cos\xi_\alpha$). For the case 2^+, l_α is unique and one needs only to select suitable values of the $E2:M1$ ratio to obtain agreement for each gamma ray.

For 1^- the coefficients are unique, and not entirely in disagreement with the experimental values. However the transition to the ground state is $M2$ so the assignment is very unlikely. For 2^-, the parameter α_α can be varied to achieve good agreement for the transitions to the excited states but only fair agreement for those to the ground state.

5.91-Mev level.—Only the 3^- and 4^- assignments can be eliminated on the basis of the approximately isotropic angular distribution. Since the transition is probably entirely to the ground state, one may rule out 0^- and 1^-, and probably also 1^+, on the basis of intensity. This leaves $2^\pm$, 3^+, and 4^+ as possible assignments.

6.02-Mev level.—As in the case of the 4.77-Mev level, the large amount of anisotropy in the angular distribution makes it possible to obtain a definitive assignment. Only with a spin and parity of 4^+ can the values $A_2=-0.80$, $A_4=2.0$ be achieved, for $\alpha_\gamma=3.0$. The theoretical curve, corrected for solid angle, is drawn in Fig. 12.

CONCLUSION

The assignment of 2^+ to the 4.77-Mev level is not inconsistent with other evidence. Bonner and Cook[7] have pointed out that the level probably has even parity because the very low yield at the threshold of the reaction $Be^9(d,n)B^{10}$ suggests emission of *p*-wave neutrons. Wilkinson and Jones[1] selected a spin of one for this level because of the strength of the transition to the 1^+ level at 0.72 Mev compared to that to the 3^+ ground state. The branching ratio of 11:1, however, does not seem extreme enough to rule out a 2^+ assignment which allows $M1$ and $E2$ for both transitions.[9]

The levels at 5.11 and 5.16 Mev are puzzling. The analysis of angular distributions[6] in the reaction $Be^9(d,n)B^{10}$, on the basis of stripping theory, indicates at least one of the levels, and quite possibly both, have negative parity and spin one or two. The large yield observed at threshold in the same reaction leads to the

[9] H. Warhanek, Phil. Mag. (to be published), has also studied the 4.77-Mev level in B^{10} by measuring the angular distributions of the gamma rays. He obtains substantially the same distribution and comes to the same conclusions, namely, that the spins 0, $1^\pm$, 2^- have to be excluded but that 2^+ and 3^+ are possible assignments. We are grateful to him for sending us an account of his work before publication.

same conclusion[10] since it suggests predominantly s-wave interaction. Hence it was natural to suppose that negative parity should be associated with the level at 5.11 Mev in view of the apparent absence of transitions to lower states of the same isotopic spin but positive parity, for which $E1$ transitions would be suppressed. The observation of transitions in the present work weakens this argument, but hardly justifies the contrary supposition of negative parity for the 5.16-Mev level instead. Moreover Wilkinson and Clegg[11] have observed a strong transition to the 5.11-Mev level from a higher level, with probable quantum numbers $I=1^-$, $T=0$, in the $Be^9(p,\gamma)B^{10}$ reaction. It is tempting, therefore, as these authors point out, to attribute $E1$ character to this radiation and quantum numbers $I=2^+$, $T=1$ to the 5.11-Mev level. In support of this possibility, there is now the observation that the most satisfactory fit to the angular distribution of gamma rays is achieved with $I=2^+$.

However, the measured angular distributions favor positive parity (and a spin of one or two) for the 5.16-Mev state also, the only serious possibility of negative parity being 2^-. The choice 1^+ has the advantage that the strength of the resonance could be attributed to its formation by s-wave alpha particles. In view of all these discordant observations, assignments to both these levels must await additional evidence.

The two levels at 5.91 and 6.02 Mev are interesting. They undoubtedly correspond to two of the three closely spaced levels near 6 Mev observed[7] with slow neutrons from the reaction $Be^9(d,n)B^{10}$. In the neutron experiment, the three levels show about the same yield. In the alpha-capture process there is obviously a marked difference in the yields, although the failure to detect a weak level at 6.16 Mev could be due to the neutron background discussed above. The spin possibilities of $I=2^\pm$, 3^+, or 4^+ for the 5.91-Mev level and of $I=4^+$ for the 6.02-Mev level are in agreement with the conclusions of Bonner and Cook,[7] who pointed out that both levels probably have spins ≥ 2 because of their small total widths.

In the energy region below 4 Mev, theoretical calculations on the basis of intermediate coupling[3] agree very well with the experimentally determined levels and spins in B^{10}. Although the situation around 4 and 5 Mev is not yet clarified, it is interesting to note in the higher energy range that the theory predicts two levels with spins 3 and 4 which could be identified with the levels at 5.9 and 6.0 Mev.

In both cases in which a definite assignment seems to have been reached, it appears significant that the good agreement between the experimental and theoretical curves is obtained for large ratios of $E2$ to $M1$ (approximately 2 and 9, respectively, for the 4.8- and 6.0-Mev states). This preponderance of quadrupole radiation contributes to the cumulative evidence of collective motion in many transitions even in the light nuclei.

[10] D. R. Inglis, Revs. Modern Phys. **25**, 390 (1953).
[11] D. H. Wilkinson and A. B. Clegg, Phil. Mag. **1**, 291 (1956); A. B. Clegg, Phil. Mag. **1**, 1116 (1956).

TABLE III. Comparison of experimental and theoretical angular distributions. If the experimental values of A_2 and A_4 (Table II) can be obtained theoretically for a given assignment, the condition for this agreement is listed (unless the theoretical values are unique) and the assignment is labeled P (Possible). If, on the other hand, the theoretical values of A_2 and A_4 as listed are incompatible with experiment, the assignment is marked N (Not possible). Borderline situations are labeled U (Uncertain). $I_\alpha(l)$ and $I_\gamma(l)$ denote, respectively, the alpha-particle and gamma-ray intensities with angular momentum equal to l.

Level in B^{10} (Mev)	Assignment	γ ray (Mev)	Requirements of this assignment	Conclusion
4.77	0^-	All	$A_4=A_2=0$	N
	$1^\pm$, 2^-	4.0	$A_4=0$	N
	2^+	4.0	$I_\gamma(2)/I_\gamma(1)=1.8$	P
		0.7	$A_4\simeq A_2\simeq 0$	P
	3^-	4.0	$A_4=-0.56$, $A_2=1.33$	N
	3^+	4.0	$I_\alpha(4)/I_\alpha(2)=0.92$	P
		0.7	$A_4\simeq A_2\simeq 0$	P
5.11	0^-	All	$A_4=A_2=0$	N
	$1^\pm$	5.1	$A_4=0$, $A_2\geqslant -0.10$	N
	2^-	5.1	$A_4=0$, $A_2\geqslant -0.18$	N
	2^+	5.1	$I_\gamma(2)/I_\gamma(1)=0.06$ or ∞	P
	3^-	5.1	$A_4=0$, $A_2=0.70$	N
	3^+	5.1	$I_\alpha(4)/I_\alpha(2)\simeq 1$	U
	4^-	5.1	$A_4=0$, $A_2\leqslant -0.39$	P
5.16	0^-	All	$A_4=A_2=0$	N
	1^-	5.2	$A_4=0$, $A_2=-0.10$	U
		4.4, 3.0	$A_4=0$, $A_2=-0.33$	P
	1^+	5.2, 4.4, 3.0	$I_\alpha(2)/I_\alpha(0)\simeq 1.5$	P
	2^-	5.2	$A_4=0$, $A_2\leqslant -0.05$	U
		4.4, 3.0	$I_\alpha(3)/I_\alpha(1)\geqslant 0.50$	P
	2^+	5.2	$I_\gamma(2)/I_\gamma(1)=0.02$ or 9	P
		4.4, 3.0	$I_\gamma(2)/I_\gamma(1)=0.01$ or 150	P
	3^-	5.2	$A_4=0$, $A_2=0.70$	N
		4.4, 3.0	$A_4=-0.54$, $A_2=1.33$	N
	3^+	5.2	$I_\gamma(2)/I_\gamma(1)=0.16$	P
		4.4, 3.0	$(A_4+A_2)\geqslant 0.75$	N
5.91	0^-	5.9	$A_4=A_2=0$	P
	1^-	5.9	$A_4=0$, $A_2=-0.10$	P
	1^+	5.9	$0\leqslant I_\alpha(2)/I_\alpha(0)\leqslant 1.0$	P
	2^-	5.9	$I_\alpha(3)/I_\alpha(1)\geqslant 0.15$	P
	2^+	5.9	$I_\gamma(2)/I_\gamma(1)\simeq 10$ or 0.01	P
	3^-	5.9	$A_4=0$, $A_2=0.70$	N
	3^+	5.9	$I_\gamma(2)/I_\gamma(1)\simeq 0.16$	P
	4^-	5.9	$A_4=0$, $A_2\leqslant -0.39$	N
	4^+	5.9	$I_\gamma(2)/I_\gamma(1)\simeq 0.04$	P
6.02	0^-	6.0	$A_4=A_2=0$	N
	$1^\pm$, 2^-	6.0	$A_4=0$	N
	2^+	6.0	$(A_4+A_2)\leqslant 0.50$	N
	3^-	6.0	$A_4=0$, $A_2=0.70$	N
	3^+	6.0	$A_4\leqslant 0.80$	N
	4^-	6.0	$A_4=0$	N
	4^+	6.0	$I_\gamma(2)/I_\gamma(1)=9.0$	P

ACKNOWLEDGMENT

We have profited from many stimulating conversations with D. Kurath and D. R. Inglis.