(VI 3a) and (VI 3b) of reference 12, in which ω_β and ω_γ have been replaced by limiting strong-coupling values.

One may check the rotational interpretation of the low states of Xe^{130} qualitatively in several ways: (1) the level order is consistent with the predicted order 0+, 2+, 4+, 6+. (2) One can calculate the nuclear deformation from the energy of the first excited state using the relation[14]

$$\beta^2 = 171/A^{5/3}E_2(\text{Mev}). \quad (3)$$

The result is $\beta = 0.310$, which fits very well into the systematic trend of the other Xe isotopes,[14] suggesting a regularly decreasing nuclear deformation as the closed neutron shell at $N=82$ is approached. (3) The ratios of the energies of the excited states, E_4/E_2 and E_6/E_2 deviate from the limiting strong coupling ratios in the expected direction, but the deviation is too large to receive quantitative explanation in terms of the first order correction given by Eq. (2). The comparison of theoretical and experimental ratios is shown in Table VI. It seems reasonable to interpret the Xe^{130} levels as collective rotations, but the nuclear deformation is not great enough to lend quantitative validity to the strong coupling approximation which works so well in the rare earth region and the region near uranium.

TABLE VI. Energy ratios for excited states in Xe^{130}.

	Experiment	Theory Without ΔE_I	Theory With ΔE_I
E_4/E_2	2.25	3.33	1.94
E_6/E_2	3.66	7.00	···

The authors are indebted to Dr. M. B. Sampson and the cyclotron group for making the bombardments, and to Mr. Arthur Lessor for making the chemical separations. They are also indebted to Dr. Kenneth W. Ford for many helpful discussions. The separated Te^{130} was obtained from the Oak Ridge National Laboratory.

[14] K. W. Ford, Phys. Rev. **90**, 29 (1953).

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Angular Correlations in the $Be^9(d,p\gamma)Be^{10}$ and $Be^9(d,\alpha\gamma)Li^7$ Reactions*

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The $(d,p\gamma)$ correlation at $E_d=0.84$ Mev was measured under the following conditions: (1) proton direction fixed at 0° to the deuteron beam, gamma direction varying, (2) proton direction fixed at 90° to the beam, gamma direction varying in the deuteron-proton plane, and (3) proton direction fixed at 90°, gamma direction varying in the 90° plane, perpendicular to the beam. The three correlations were different, and showed varying amounts of anisotropy. The appearance of terms in $\cos^4\theta$ in these correlations indicates that the spin of the first excited state of Be^{10} is ≥ 2. Coupled with other information on this state, this result gives a spin assignment of 2. A qualitative discussion of the correlations is given, and the effect of the deuteron stripping process is considered. The $(d,\alpha\gamma)$ correlation was also measured with the alpha direction fixed at 90° to the beam and the gamma direction varying in the deuteron-alpha plane. Failure to detect a departure from isotropy again confirms the assignment of $\frac{1}{2}$ to the spin of the first excited state of Li^7.

I. INTRODUCTION

THE electromagnetic radiation from the first excited state of Be^{10} has been studied in coincidence with short-range protons in the reaction, $Be^9(d,p)Be^{10*}(\gamma)Be^{10}$. The coincidence yield in such a reaction is, in general, a function of considerable complexity, involving the directions of the deuteron, proton, and gamma ray, as well as the deuteron energy and the properties of the various states and particles taking part in the process. The correlation function will be designated by $W(\theta_p,\theta_\gamma,\phi)$, where θ_p and θ_γ are measured with respect to the direction of the deuteron, and ϕ is the dihedral angle between the proton-deuteron and gamma-deuteron planes, all in the center-of-mass coordinate system.

The following correlation functions were measured:

(1) $W(0,\theta_\gamma,\phi)=W(0,\theta_\gamma)$. If only waves of the same parity are present in the gamma-ray transition, as will be assumed henceforward, the correlation function has reflection symmetry in the $\theta_\gamma=90°$ plane, and can be written:

$$W(0,\theta_\gamma)=\sum_{n=0}^{K} A_{2n}\cos^{2n}\theta_\gamma = W(0,180-\theta_\gamma),$$

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where K is an integer which cannot be greater than I_2 or L_γ.[1,2] I_2 is the spin of Be^{10*} and 2^{L_γ} is the multipolarity of the gamma radiation.

(2) $W(90,\theta_\gamma,180)$. If one assumes compound-nucleus formation, the participating states of the compound nucleus play an important role in determining the form of the correlation function.[3] If only states of the same parity in the compound nucleus take part, the correlation function will be symmetric about $\theta_\gamma=90°$, as before:

$$W(90,\theta_\gamma,180)=\sum_{n=0}^{K} B_{2n}\cos^{2n}\theta_\gamma=W(90,180-\theta_\gamma,180),$$

where K is again limited by I_2 or L_γ. In addition,

$$W(90,\theta_\gamma,0)=W(90,\theta_\gamma,180),$$

since $W(90,\theta_\gamma,0)$ is equivalent to $W(90,-\theta_\gamma,180)$. If, however, there are states of opposite parity, antisymmetric terms are introduced. Designating these terms by W', one obtains,

$$W'(90,\theta_\gamma,180)=-W'(90,\theta_\gamma,0)=W'(90,180-\theta_\gamma,0).$$

(3) $W(90,90,\phi)$. In general the correlation function is given by

$$W(90,90,\phi)=\sum_{n=0}^{K} C_{2n}\cos^{2n}\phi.$$

If the deuteron beam does not provide an orientation in the reaction then of course a unique correlation is obtained independent of the direction of the proton. If the reaction proceeds by means of the stripping mechanism, the correlation function may be written:[4]

$$W_s(\theta_s)=\sum_{n=0}^{N} D_{2n}\cos^{2n}\theta_s,$$

where θ_s is the angle of the gamma ray measured with respect to the propagation direction of the captured neutron in the laboratory. The integer N cannot be greater than I_2 or L_γ or l_n, the orbital angular momentum of the captured neutron.

A measurement was made also of the alpha-gamma correlation in the $Be^9(d,\alpha)Li^{7*}(\gamma)Li^7$ reaction. Since no anisotropy was detected in the $W(90,\theta_\gamma,180)$ correlation, as expected, no further measurements were made for other alpha directions.

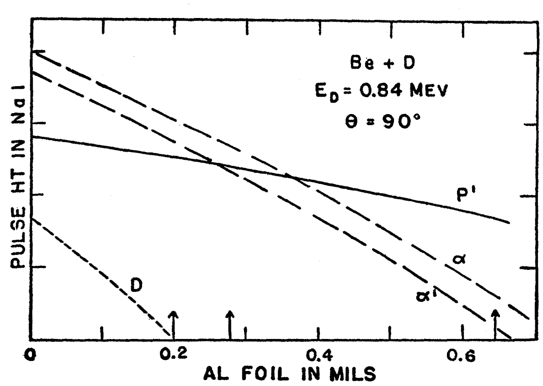

FIG. 1. Approximate pulse height with a NaI(Tl) detector of particles from Be^9+d as a function of absorber thickness.

II. APPARATUS

Sodium iodide crystals were used in conjunction with 5819 photomultiplier tubes for the detection of both the gamma rays and the protons. The crystal used in the gamma ray detector was a one-inch cube; the detector was mounted outside the target chamber and could be rotated about the axis of the chamber. In order to reduce the response of the proton detector to neutrons and gammas, thin sodium iodide crystals were used. A crystal $\frac{1}{16}$ in. thick or less was mounted inside the target chamber on a window optically coupled to an external photomultiplier tube. The crystal was covered by a 0.02-mil nickel foil.

Two cylindrical target chambers were used during the course of the experiment. One chamber was constructed of aluminum with a $\frac{1}{8}$-in. wall; the other of brass with a $\frac{1}{32}$-in. wall. Two sets of targets were employed: one consisted of thin beryllium foils mounted on thin aluminum or nickel backings, the other of thin beryllium deposits on thicker copper or tantalum backings. The thin backings were used in the observations in which the protons were detected in the forward direction. All the targets were approximately 0.07 mg/cm^2.

Pulses from the detectors were amplified and analyzed in single-channel pulse-height analyzers, which were modifications of the circuit designed by Roulston.[5] The outputs of the analyzers actuated blocking oscillators which presented uniform pluses to the coincidence circuit and to the scalers which recorded the single-channel counting rates. The coincidence circuit was a modification of one used previously,[2] with a resolving time of about 10^{-7} sec. The accidental coincidence rate was monitored continuously by means of a second, similar coincidence circuit which received pulses delayed by 0.75 μsec from one of the channels, and underlayed pulses from the other.

[1] Biedenharn, Arfken, and Rose, Phys. Rev. **83**, 586 (1951). Other possible limitations on K are discussed in this and the following reference.
[2] C. M. Class and S. S. Hanna, Phys. Rev. **87**, 247 (1952).
[3] The statements under (2) and (3) follow directly from an examination of the general correlation function obtained from the function given in reference 1 by suitable modification to include multiple states of the compound nucleus.
[4] Biedenharn, Boyer, and Charpie, Phys. Rev. **88**, 517 (1952); L. J. Gallaher and W. B. Cheston, Phys. Rev. **88**, 684 (1952); G. R. Satchler and J. A. Spiers, Proc. Phys. Soc. (London) **A65**, 980 (1952).
[5] K. I. Roulston, Nucleonics **7**, No. 4, 27 (1950).

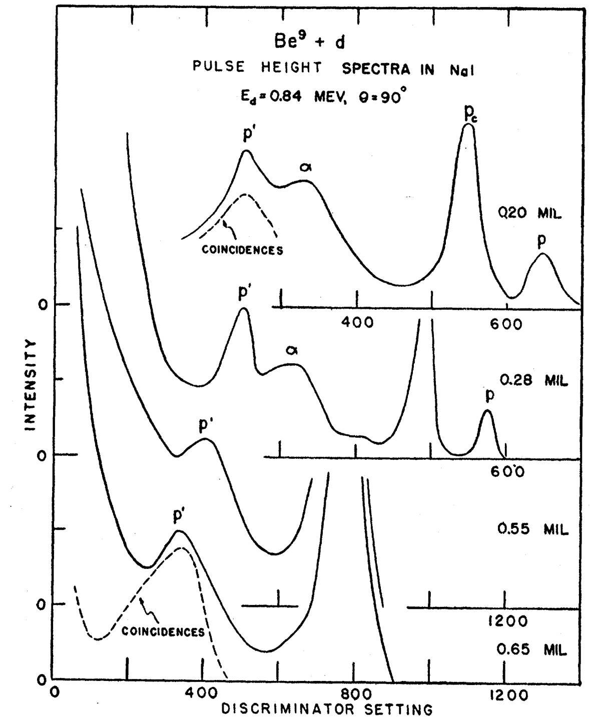

FIG. 2. Pulse height spectra for different absorbers. The two lower curves were taken at increased gain but are plotted to approximately the same energy scale as the two upper curves. The high-energy end of the spectra in the lower curves is badly distorted by over loading in the amplifier. Curves labelled coincidences show the particles in coincidence with 3.4-Mev gamma radiation.

The deuteron beam, obtained from an electrostatic accelerator, had an energy of 0.84 Mev for practically all the measurements.

III. THE $Be^9(d,p)Be^{10*}(\gamma)Be^{10}$ REACTION

The observed charged-particle spectrum included two groups of protons, two groups of alpha particles, and two groups of tritons from Be^9+d, proton groups from $C^{12}+d$ and $O^{16}+d$, and elastic deuterons. In order to avoid overloading the detector and the circuits, it was necessary to eliminate the elastic deuterons by inserting a suitable amount of absorbing foil between target and crystal. Figure 1 gives the approximate pulse heights of the various relevant groups as a function of thickness of aluminum foil. The curves were calculated using the pulse height data on NaI(Tl) of the Illinois group.[6] The target chamber was provided with a foil wheel incorporating four foils, and the spectra obtained are shown in Fig. 2. p, p', and α indicate groups from the beryllium reaction, and p_c is the proton group from carbon. In the two lower curves for the thicker foils, a higher grain was used and the upper end of the spectrum is badly distorted by overloading in the amplifier. In the two upper curves the short-range proton group p' is superimposed on the two alpha groups (not resolved). In the lower curves the alphas are well below the short-range protons. In all the spectra the very broad group of short-range tritons from the beryllium reaction[7] also falls in the region of the p' group.

As in the case of the charged particles, the gamma-ray spectrum is very complex.[8] In addition to the 3.36-Mev gamma from $Be^9(d,p)Be^{10*}$, there are at least seven gamma rays from $Be^9(d,n)B^{10*}$, a 0.87-Mev gamma from $O^{16}(d,p)O^{17*}$, and a 3.1-Mev radiation from $C^{12}(d,p)C^{13*}$. The sodium iodide spectrum of these gamma rays has been investigated in detail in this laboratory, and the results will appear in a separate publication. Under low resolution, one obtains the spectrum shown in Fig. 3. The broad peak contains the multiple structure due to pair production and Compton scattering in the crystal of the following gamma rays: 3.6 and 2.9 Mev from B^{10*}, 3.4 Mev from Be^{10*}, and 3.1 Mev from C^{13*}.

The p-γ coincidences were obtained as follows. The gamma-ray detector was calibrated with radiation of known energy. With a wide, 7.5-volt channel, the gamma-ray analyzer was set to record radiation of about 3.4 Mev. The proton analyzer, also with a 7.5-volt channel, was then set in the region of the short-range proton group, and a coincidence spectrum was obtained by varying the setting of the proton analyzer. Typical coincidence curves obtained are shown in Fig. 2. With the proton channel on the peak of the coincidence curve, a coincidence spectrum was then obtained for the gamma rays. A typical curve is shown in Fig. 3.

Coincidence curves were obtained in this manner before nearly every run. Despite the fact that all these

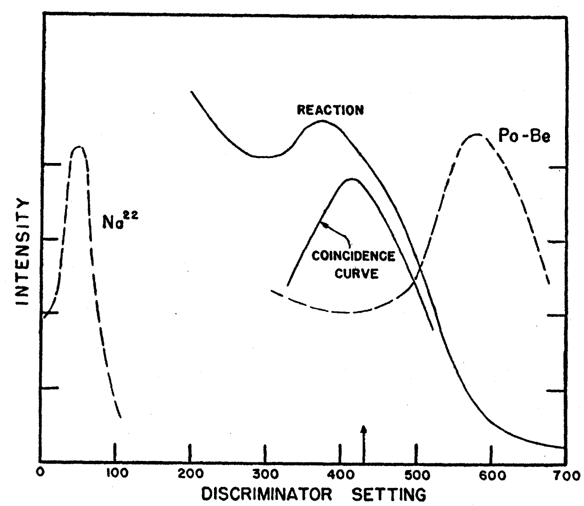

FIG. 3. Pulse height spectra for the gamma radiation from Be^9+d (labelled "reaction"), Na^{22} (0.5 Mev), and Po-Be (4.4 Mev). The coincidence curve shows the radiation in coincidence with short-range protons.

[6] Taylor, Jentschke, Remley, Eby, and Kruger, Phys. Rev. 84, 1034 (1951).

[7] I. Resnick and S. S. Hanna, Phys. Rev. 82, 463 (1951).

[8] Rasmussen, Hornyak, and Lauritsen, Phys. Rev. 76, 581 (1949).

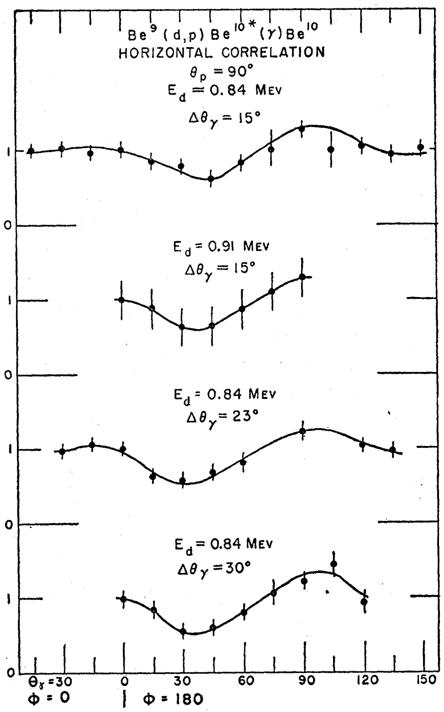

FIG. 4. The $W(90,\theta_\gamma,180)$ and $W(90,\theta_\gamma,0)$ correlations. Measurements were made from $\theta_\gamma=0$ to $45°$ in the $\phi=0$ plane and from $\theta_\gamma=0$ to 150 in the $\phi=180$ plane. $\Delta\theta_\gamma$ indicates the angular aperture of the gamma counter.

measurements indicated that the proton-gamma coincidences were well isolated, other sources of coincidene radiations may be considered. They are listed in Tablt I. With the channel of the gamma detector set to exclude radiation below about 3 Mev, the alpha-gamma and proton-gamma radiations from Be^9 and O^{16}, respectively, are eliminated. The absorbing foil completely stops the protons from the C^{12} reaction. There remains the gamma-gamma and also perhaps neutron-gamma coincidences from the $Be^9(d,n\gamma)B^{10}$ reaction. With a wide channel set on 3.4 Mev, the gamma-ray detector will also record some of the 2.9- and 3.6-Mev radiation from the B^{10} nucleus. These gamma rays are both in coincidence with a 1.3-Mev neutron; the 2.9-Mev radiation is in coincidence also with a 0.7-Mev gamma ray. The use of thin sodium iodide crystals and energy discrimination makes the proton channel very insensitive to these radiations. It is believed that the rise in the coincidence spectrum at very low pulse height in the lowest curve of Fig. 2 is due to coincidences between 2.9-Mev gamma rays in the gamma detector and 0.7-Mev gamma rays in the proton detector. As a further test of the purity of the desired coincidences, at the maxima of the coincidence spectra, an additional foil was placed between the target and the proton detector so as to completely stop the protons with very little effect on the neutrons and gammas. The coincidence rate obtained in this manner was negligible compared to the rate obtained without the additional foil.

The angular correlation measurements were obtained by observing, at each angle of the gamma counter, the coincidence yield, the single channel yields of both detectors, and the integrated beam current. The time of observation at each angle ranged from 10–30 min. In nearly all the correlations runs the angular settings were repeated at least once, and sometimes as many as eight times.

The 90° setting of the proton counter was made in the laboratory system of coordinates. Hence, the 90° correlations are actually for $\theta_p=95°$(c.m.). The effect of this 5° shift on the correlations is considered below. If the coincidence yield is normalized to the proton yield, it is necessary to consider the following: (1) variation in the distance of the gamma counter; (2) absorption of the radiation in the target backing; (3) center-of-mass correction on the gamma yield, and (4) variation in the energy and hence the efficiency of detection of the gamma ray. In most instances these effects were small compared to the experimental uncertainty in the measurements. Suitable corrections have been applied in those cases in which the effects were appreciable.

(A) The $W(90,\theta_\gamma,180)$ Correlation

The aluminum target chamber was mounted with its axis vertical. The beam, the proton detector (at 90°), and the rotating gamma detector were in a horizontal plane. The target plane was vertical and at an angle with respect to the beam which was varied between 30° and 60° in various parts of the experiment. The aluminum foil thickness was either 0.20 or 0.28 mil producing the charged particle spectra at the top of Fig. 2.

Four measurements of the angular correlation were made under somewhat different conditions. The results are shown in Fig. 4. A pronounced variation of the coincidence yield with angle is observed. The data from the four runs were averaged together and plotted in Fig. 5(A). The correlation appears to have the property that

$$W(90,\theta_\gamma,0)=W(90,180-\theta_\gamma,180).$$

Accordingly, data in the $\theta=0°\rightarrow90°$, $\phi=0°$ quadrant have been plotted at the corresponding points in the

TABLE I. Coincident radiations from deuteron bombardment of Be^9 and target impurities. Particle energies are computed for $E_d=0.84$ Mev, $\theta=90°$ and an absorbing foil of 0.2-mil aluminum

Target	Particle	Gamma ray
Be^9	p', 1.5 Mev	3.4 Mev
Be^9	α', 3.6 Mev	0.5 Mev
Be^9	n, γ	2.9, 3.6 Mev
O^{16}	p', 1.5 Mev	0.9 Mev
C^{12}	p', 0 Mev	3.1 Mev

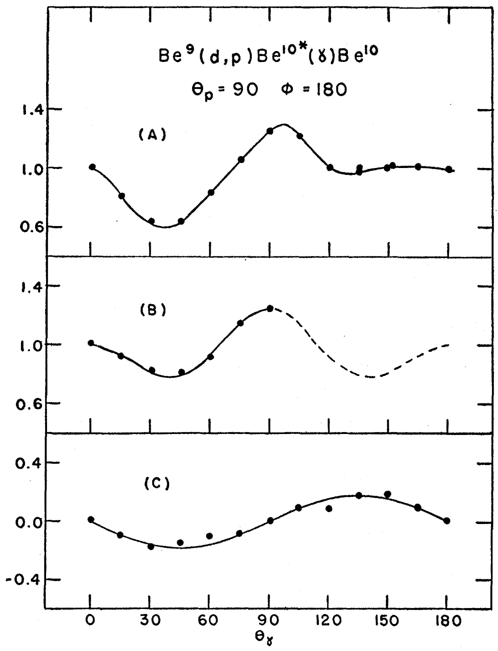

FIG. 5. (A) shows an average of the four runs in Fig. 4. Points in the $\theta_\gamma=0°\rightarrow 90°$, $\phi=0°$ quadrant have been plotted in the $\theta_\gamma=90°\rightarrow 180°$, $\phi=180°$ quadrant. (B) shows the data in (A) folded about $\theta_\gamma=90°$ with corresponding points averaged. (C) shows the result of subtracting the points in (B) from the data in (A).

$\theta=90°\rightarrow 180°$, $\phi=180°$ quadrant, producing a smooth curve in this quadrant. In order to display the symmetric part of this curve, it was folded about $\theta_\gamma=90°$ and corresponding points averaged to produce the symmetric curve in Fig. 5(B). Subtracting the points in this plot from the observed yield, gives the antisymmetric curve in Fig. 5(C).

The data in Fig. 5(B) are fitted very well by the least-square curve,

$$W(90,\theta_\gamma,180)=1.24(1-1.23\cos^2\theta_\gamma+1.03\cos^4\theta_\gamma),$$

which is the curve drawn in the figure. The points in Fig. 5(C) have been fitted with the curve,

$$W'(90,\theta_\gamma,180)=-0.20\sin 2\theta_\gamma,$$

which seems to provide a good description of the data. Since the dependence of the correlation function on the angle ϕ is not known, it is not possible to obtain an exact modification of these functions for the finite apertures of the detectors. An approximate calculation, assuming the dependence on ϕ to be negligible over the apertures, indicates that the coefficients should be be increased by 14–18 percent.

(B) The $W(90,90,\phi)$ Correlation

The brass target chamber was mounted horizontally with its axis along the beam direction. The target was oriented so that its normal made angle of about 60° with the beam and with the direction of the proton counter (at 90° to the beam). The gamma counter was rotated in the vertical $\theta_\gamma=90°$ plane. The aluminum foil was 0.65 mil, producing the spectrum in the lowest curve of Fig. 2.

Two separate runs were made. Their average is shown in Fig. 6. A very small correlation is observed, at most 10 percent. Because this correlation was performed under different conditions, the $W(90,\theta_\gamma,180)$ correlation was remeasured briefly. No great accuracy was achieved, because of the difficulty of making settings and measurements on the gamma counter in the horizontal plane. The results are given in Fig. 6. They are in substantial agreement with the earlier measurements on the $W(90,\theta_\gamma,180)$ correlation.

(C) The $W(0,\theta_\gamma)$ Correlation

The brass target chamber was reoriented with its axis vertical and with the proton detector at 0° to the beam. Beryllium targets on thin backings were used so as to allow protons to reach the detector. With an 0.9 mil absorbing foil, a spectrum similar to the lowest curve of Fig. 2 was obtained. The location of the beam tube and the proton detector limited the settings of the gamma counter to angles between 45° and 150°. In some of the runs the gamma counter was retracted at the extreme angles to obtain greater angular coverage in θ_γ, necessitating a large inverse square correction at these angles.

All the observations made on this correlation are shown in Fig. 7, plotted to the same scale as for the other correlations. A weighted average of all the data is given at the bottom of the figure.

In this correlation there appears to be a small but definite departure from isotropy which is symmetric about $\theta_\gamma=90°$. A satisfactory fit to the data can be obtained by including terms up to $\cos^4\theta$. A least square

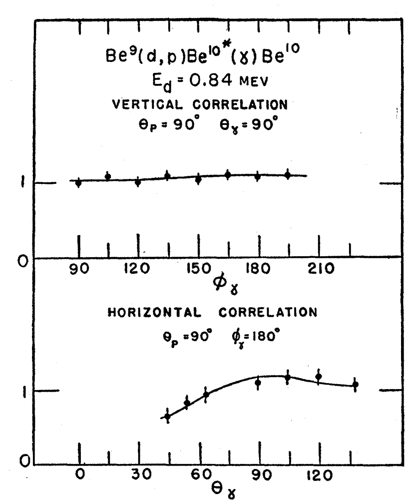

FIG. 6. The $W(90,90,\phi)$ correlation and the $W(90,\theta_\gamma,180)$ correlation taken with the same physical and geometrical arrangement.

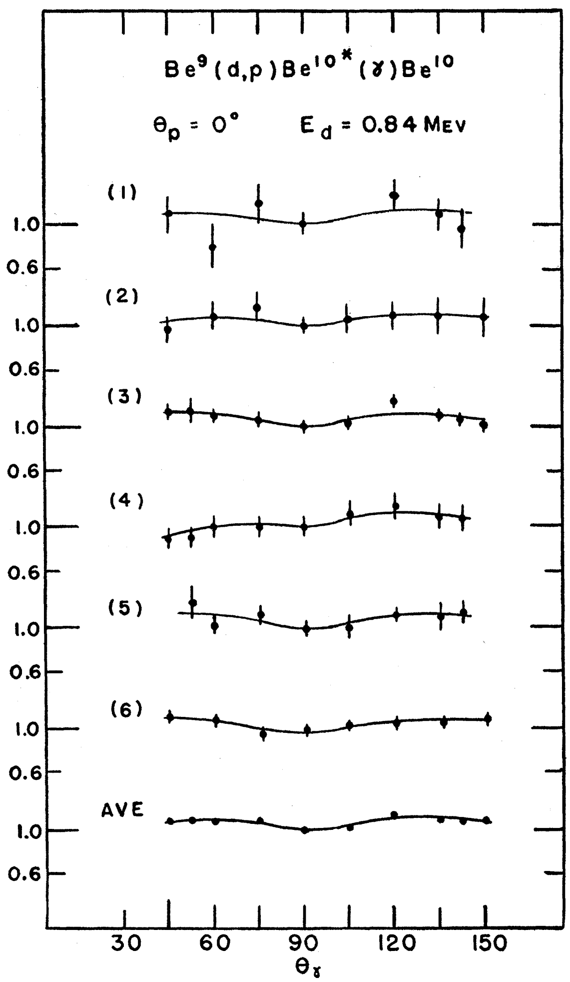

FIG. 7. The $W(0,\theta_\gamma)$ measurements and a weighted average of all the data.

analysis gives

$$W(0,\theta_\gamma)=1.03(1+0.20\cos^2\theta_\gamma-0.23\cos^4\theta_\gamma).$$

The correction for the detector apertures would increase the coefficients by about 15 percent. Although these coefficients are fairly large, it is clear that they are subject to considerable uncertainty. Over the range of angles available, the measured coincidence yield varies by about 10 percent, which is only two or three times the combined experimental and statistical error.

IV. DISCUSSION

The appearance of a term in $\cos^4\theta_\gamma$ in the symmetric part of the $W(90,\theta_\gamma,180)$ correlation and in the $W(0,\theta_\gamma)$ correlation places a lower limit of two on the spin of the first excited state of Be^{10}. Several investigators[9] have observed the angular distribution of the protons with respect to the beam at bombarding energies from 3–15 Mev. The appearance of a forward peak in the distribution, corresponding to the $l_n=1$ peak in the stripping reaction, places an upper limit of three on the spin of Be^{10*}, and indicates even parity for the state. These experiments, therefore, limit the assignment to 2^+ or 3^+. With an assignment of 0^+ for the ground state, the radiation is either E2 or M3. Thomas and Lauritsen[10] have measured the internal pair formation coefficient of this gamma ray, and have found it to be consistent only with E1, M1, or E2 radiation. Hence, an assignment of two to the spin of the first excited state of Be^{10} is indicated, as is the case in a large number of the even-even nuclei.[11] The choice of two, instead of three, for the spin is supported by the very good fit that is obtained in the $W(90,\theta_\gamma,180)$ correlation with a function containing terms only up to $\cos^4\theta_\gamma$. Although the lack of a term in $\cos^6\theta$ could be ascribed to other circumstances, it is a natural result of the assignment of spin two.

The antisymmetric term observed in the $\theta_p=90°$, $\phi=180°$ correlation, is of interest. It can be attributed in part at least to the fact that the correlation was actually obtained at $\theta_p=95°$ in the c.m. coordinate system. Hence terms in the general correlation function containing $\cos\theta_p$ which vanish at $\theta_p=90°$, are small but not negligible at $\theta_p=95°$. These terms arise from interference among magnetic substates in the triple correlation process[1] and provide a dependence on θ_γ, having the symmetry observed, although not necessarily of the simple form $\sin 2\theta_\gamma$.[12] As mentioned in the introduction, the same behavior, even at $\theta_p=90°$, can be ascribed formally to the presence in the compound nucleus of two or more participating states, not all of the same parity. The proton and neutron angular distributions from Be^9+d, at bombarding energies in the range of the present investigation, show asymmetries which can be attributed to interfering states in the compound nucleus.[7,13] These same distributions also give evidence for some deuteron stripping at these bombarding energies. It is therefore interesting to examine the stripping angular correlation in connection with the measurements in the present investigation.

It is clear that the three correlations that were studied are not compatible with the stripping process alone. The stripping correlation should be a function only of the angle between the gamma ray and the direction of recoil of the Be^{10*} nucleus. When the protons are emitted at 0°, the axis of the stripping correlation coincides with the proton direction. When the protons are observed at 90°, the axis turns out to be at 45° to the beam, in the $\phi=180°$ plane.

A stripping angular correlation can be computed for each channel spin entering the stripping process. With

[9] F. A. El Bedewi, Proc. Phys. Soc. (London) A65, 64 (1952); C. F. Black, Phys. Rev. 87, 205 (1952); Fulbright, Bruner, Bromley, and Goldman, Phys. Rev. 88, 700 (1952).

[10] R. G. Thomas and T. Lauritsen, Phys. Rev. 88, 969 (1952).

[11] G. Scharff-Goldhaber, Phys. Rev. 90, 587 (1953).

[12] *Note added in proof.*—We have recently measured the correlation for a setting in the laboratory corresponding to $\theta_p=90°$ in the center-of-mass system. The antisymmetric term appears to be reduced, but not eliminated, at this setting.

[13] Pruitt, Hanna, and Swartz, Phys. Rev. 87, 534 (1952).

$l_n=1$,

$$W_s(\theta_s)=1+\cos^2\theta_s \text{ for channel spin 1,}$$

$$W_s(\theta_s)=1-\cos^2\theta_s \text{ for channel spin 2.}$$

In the $\theta_p=0°$ correlation, $\theta_s=\theta_\gamma$, and it is not possible, on the basis of symmetry, to separate a stripping correlation of the form $1+D_2\cos^2\theta_s$ from the observed correlation. The stripping process, however, cannot account for a term in $\cos^4\theta$.

In the $\theta_p=90°$, $\phi=180°$ correlation, $\theta_s=\theta_\gamma-45°$,

$$\text{and } \cos^2\theta_s=\tfrac{1}{2}(1+\sin 2\theta_\gamma).$$

Hence the term in $\sin 2\theta_\gamma$ observed in this correlation could be attributed in part at least to the stripping process. $W_s(\theta_s)$ would have the form $1+D_2\cos^2\theta_s$, with $D_2<0$. Removal of a correlation of this type from the $W(90,90,\phi)$ and $W(0,\theta_\gamma)$ correlations would in both cases increase the observed departure from isotropy. It is not possible to carry out an analysis in any detail because of the unknown parameters involved, especially in view of the coherent nature of the stripping and compound nucleus processes. It would be interesting to observe the $(d,p\gamma)$ correlation at other deuteron energies and proton angles, in particular at the maximum of the stripping distribution.

V. THE $Be^9(d,\alpha)Li^{7*}(\gamma)Li^7$ REACTION

Following the measurement of the $W(90,\theta_\gamma,180)$ correlation in the $(d,p\gamma)$ process, a measurement of the $(d,\alpha\gamma)$ correlation was obtained with the same experimental arrangement. It was necessary only to change the setting of the gamma channel from 3.4 Mev to 0.5 Mev, and make a small adjustment in the channel of the charged particle detector. With an 0.20-mil Al absorber, (see Fig. 2), the alpha coincidence curve was observed at slightly higher pulse heights than the proton coincidence curve shown in Fig. 2.

TABLE II. Summary of experiments in which no anisotropy has been detected in the emission of the 0.48-Mev gamma ray from Li^{7*}.

Reaction	Correlation	Beam energy, Mev	Ref.
$Li^7(p,p'\gamma)Li^7$	$(p\gamma)$	0.8−1.1	a
$B^{10}(n,\alpha\gamma)Li^7$	$(\alpha\gamma)$	thermal	b
$Li^6(d,p\gamma)Li^7$	$(d,p\gamma)W(0,\theta_\gamma)$	0.7−0.8	c
	$(d,p\gamma)W(90,90,\phi)$	0.63	d
	$(d,p\gamma)W(90,90,\phi)$	0.50	e
	$(d,p\gamma)W(116,\theta_\gamma,180)$	0.41	f
	$(d,p\gamma)W(90,90,\phi)$	0.60	g
	$(d,p\gamma)$	1.00	h
	(d,γ)	0.70	c
$Be^9(d,\alpha\gamma)Li^7$	$(d,\alpha\gamma)W(152,\theta_\gamma,180)$	0.40	i
	$(d,\alpha\gamma)W(90,\theta_\gamma,180)$	0.84	

[a] R. M. Littauer, Proc. Phys. Soc. (London) A63, 294 (1950).
[b] B. Rose and A. R. W. Wilson, Phys. Rev. 78, 68 (1950).
[c] See reference 2.
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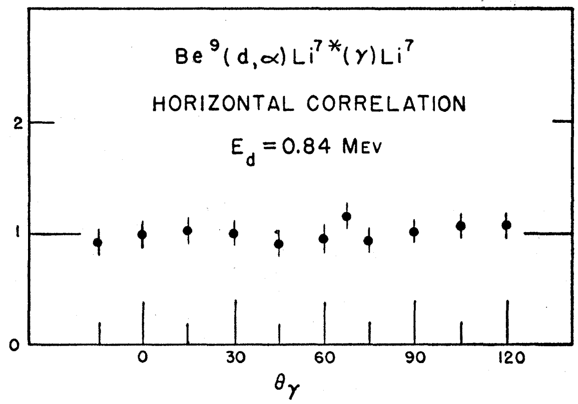

FIG. 8. The $W(90,\theta_\gamma,180)$ correlation for the (d,α,γ) process.

In view of the many experiments, cited in Table II, in which the 0.48-Mev radiation from Li^{7*} is found to be isotropic, it was fully expected to be isotropic in this case also. A measurement of the correlation therefore would provide a good test of the equipment and the method of energy selection. On the other hand, it would give one more "determination" of the spin of Li^{7*}. In this instance a comparison with the markedly anisotropic $(d,p\gamma)$ correlation would be fairly convincing, since both reactions originate in the same manner and involve the same states in the compound nucleus. The $(d,\alpha\gamma)$ correlation has recently been measured by Uebergang and Tanner[15] under different conditions, with an isotropic result.

The results of the present measurement are shown in Fig. 8. It was not thought worthwhile to achieve the same accuracy in this correlation as in the $(d,p\gamma)$ measurements. If the data are folded about $\theta_\gamma=0°$ and 90°, the resulting correlation can be considered isotropic to within about 5 percent. It should be noted that in this measurement the discrimination between the α-γ and p-γ processes is not complete, since the gamma counter, set on 0.5 Mev, will respond to some 3.4-Mev radiation, and the protons and alphas are imperfectly resolved in the particle channel. There is perhaps a trace of the $(d,p\gamma)$ correlation discernible in the $(d,\alpha\gamma)$ measurement in Fig. 8.

A summary of the correlation experiments on the 0.48-Mev gamma ray is given in Table II. There is now abundant evidence for the isotropic distribution of this gamma ray under a variety of conditions in a number of reactions, leading to the assignment of $\frac{1}{2}$ for the spin of the first excited state of Li^7.

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