Deuteron Bombardment of Be^9 and Classification of Levels of B^{10}†

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Previous measurements on the $Be^9(d,n)B^{10}$ neutron spectrum at 0° and 80° have been extended to 10°, 30°, and 45° to check the energy level assignments and to deduce the parity of the levels from a Butler analysis of the angular distributions. The observed neutron groups correspond to levels of B^{10} at 0.72, 1.75, 2.15, 3.53, 4.78, 5.14 (doublet), 5.37 (?), 5.58, 5.72 (?), 5.93, 6.12 (possibly doublet), 6.38, 6.58, and 6.77 Mev. The estimated uncertainty is 0.06 Mev for the first five states of B^{10} and 0.04 Mev for the higher energy levels. The Butler analysis of the angular distribution data indicates that the ground state and the first four excited states of B^{10} are of even parity and that both components of the 5.14-Mev doublet are probably odd parity states. Parity assignments for some of the other energy levels have been attempted. The spins of these states cannot be uniquely determined on the basis of the Butler analysis, but the possible spin limits are listed. A $Be^9(d,p)Be^{10}$ exposure was also made. There do not appear to be any states in Be^{10} between the ground state and the known 3.37-Mev level.

INTRODUCTION

In the past couple of years, a great deal of progress has been made in the determination of the values of the excitation energies of light nuclei. While large energy regions in various nuclei[1] are still unexplored, it is desirable to attempt a more complete description of particular states in the hope that it may contribute to an understanding of nuclear structure and nuclear forces.

There are a number of methods available for the determination of spins and parities. The one with which this investigation is concerned is the deuteron stripping theory of Butler.[2] The theory has been applied in this work to the angular distributions of neutrons resulting from the deuteron bombardment of Be^9.

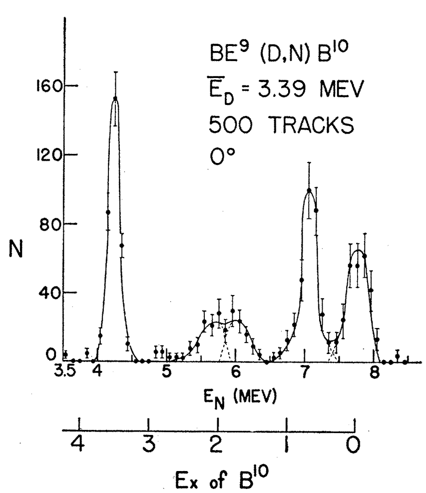

FIG. 1. 0° data. N is the relative number of neutrons/100-kev interval.

EXPERIMENTAL PROCEDURES—(d,n) EXPOSURE

Deuterons from the Wisconsin electrostatic generator, after passing through the 1-meter cylindrical analyzer and a $\frac{1}{8}$-inch defining aperture in 0.01-inch tantalum, struck a thin Be^9 metallic target[3] mounted on a tantalum backing. The average deuteron energy was 3.39 Mev. The resulting neutrons were observed by means of NTA (Eastman-Kodak) emulsions, 200 microns thick, mounted 10 centimeters from the target, and at angles of 0°, 10°, 30°, 45°, and 80° to the incident beam.

The following processing technique, suggested by Mrs. M. J. Wilson Laubenstein, was employed: The plates, supported in a Lucite holder, were immersed in a solution of 1 part D-19 and 1 part distilled water. This solution was at 5°C. After 30 minutes, 4 parts of distilled water at room temperature (approximately 22°C) were added. The plates remained in this mixture of 1 part D-19 to 5 parts distilled water for 30 minutes, and were then placed in a solution of 1.5 percent acetic acid at 5°C for another thirty minutes. After this stopping treatment, the plates were transferred to a hypo solution (30 percent sodium hyposulfite by weight, 70 percent distilled water) for a length of time 1.5 times the period necessary for clearing the emulsion. The plates were then washed in running water for about 6 hours, dipped in a solution of 50 percent ethyl alcohol and 50 percent water for a couple of minutes, and then allowed to dry in a reasonably dust-free room.

The acceptance criteria that were applied to the proton recoil tracks are similar to the ones discussed in a paper by Johnson, Laubenstein, and Richards.[4] The range-energy relation used to compute the energy of

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[1] Hornyak, Lauritsen, Morrison, and Fowler, Revs. Modern Phys. 22, 291 (1950).
[2] S. T. Butler, Proc. Roy. Soc. (London) A208, 559 (1951).
[3] The foil was kindly furnished by Dr. Hugh Bradner. Its thickness corresponds to a stopping power of approximately 50 kev for deuterons of 3.5 Mev.
[4] Johnson, Laubenstein, and Richards, Phys. Rev. 77, 413 (1950).

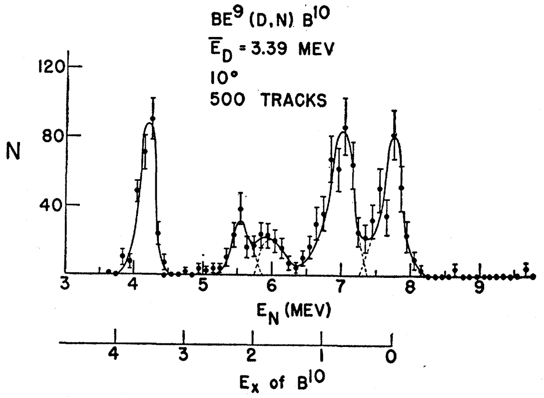

FIG. 2. 10° data. N is the relative number of neutrons/100-kev interval.

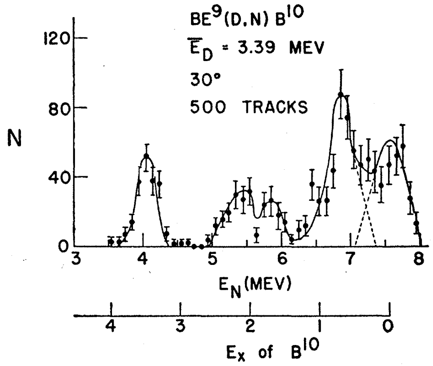

FIG. 4. 30° data, $E_x<4$ Mev. N is the relative number of neutrons/100-kev interval.

the recoil protons has been discussed previously.[5] The data, after being corrected for geometry[6] and for variation of the neutron-proton scattering cross section,[7] is plotted as relative number of neutrons/energy interval (N) *versus* the neutron energy. For the angular distribution data, the total number of neutrons in a given group is usually obtained by adding the corrected experimental ordinates. In some cases, neutron groups have not been completely resolved, and thus decisions have had to be made as to whether neutrons were part of one group or of another. Whenever the choice has not been obvious, dotted lines on the data plots show the lines of demarcation. The uncertainties indicated for the angular distribution points are statistical uncertainties only. They do not include possible errors in the assignment of the neutrons to the group.

The total number of neutrons in a given group, at a given laboratory angle, were then converted to the center-of-mass system values by means of Moskow's tables.[8] The relative number of neutrons is then corrected for the different areas scanned at the various angles. A $1/r^2$ correction is not necessary since strips of approximately equal lengths are scanned at all angles, the only varying parameter being the number of strips. Thus angular distribution points may be plotted. These are directly proportional to the differential cross section for the reaction to a given state of B^{10}, and therefore comparison may be made with Butler's theoretical curves.

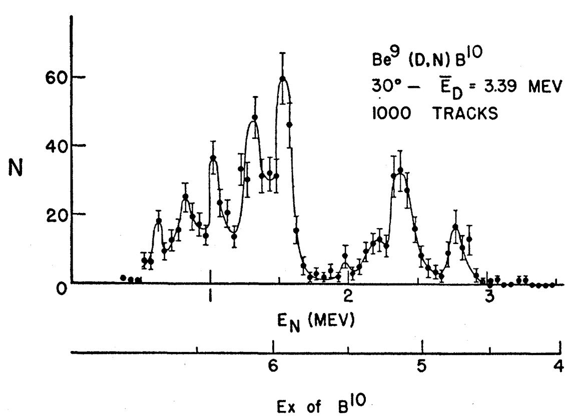

FIG. 3. 30° data, $E_x>4$ Mev. N is the relative number of neutrons/50-kev interval.

EXPERIMENTAL RESULTS—(d,n) EXPOSURE

The results of a first exposure on the $Be^9(d,n)B^{10}$ reaction, carried out under conditions similar to the ones in this exposure, but with plates exposed only at 0° and 80°, have been reported previously.[9] This first exposure will be designated throughout the remainder

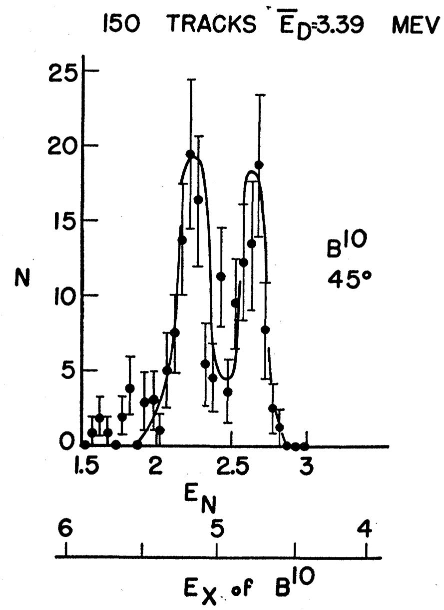

FIG. 5. 45° data, 4.5 Mev$<E_x<$5.8 Mev. N is the relative number of neutrons/50-kev interval.

[5] Richards, Johnson, Ajzenberg, and Laubenstein, Phys. Rev. **83**, 994 (1951).
[6] H. T. Richards, Phys. Rev. **59**, 796 (1941).
[7] R. K. Adair, Revs. Modern Phys. **22**, 249 (1950).
[8] Morris Moskow, unpublished Master's essay, The Johns Hopkins University (1948).
[9] Fay Ajzenberg, Phys. Rev. **82**, 43 (1951).

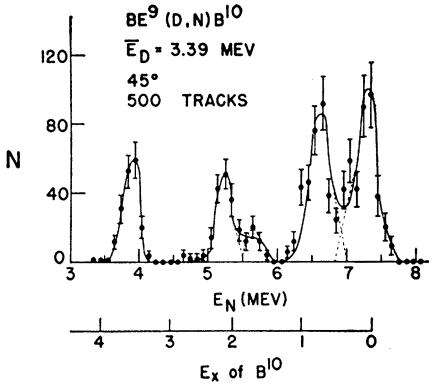

FIG. 6. 45° data, $E_x<4$ Mev. N is the relative number of neutrons/100-kev interval.

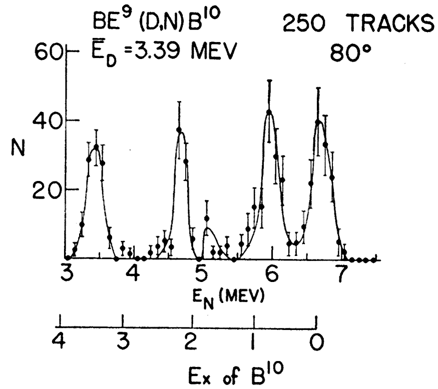

FIG. 7. 80° data. N is the relative number of neutrons/100-kev interval.

of the paper by I, and the present exposure by II. Exposure II was made primarily to obtain the angular distributions of the neutrons from the first five states of B^{10}, because from I it was known that the first five states could be resolved fairly satisfactorily. Therefore, only "long" tracks were measured at 0°, 10°, and 80°. At 30° and 45° shorter tracks were also measured to aid in checking on some "doubtful" high energy levels tentatively identified during the scanning of I. Five hundred "long" tracks have been measured on each of the following plates: II-0°, II-10°, II-30°, and II-45°. Two-hundred and fifty long tracks have been measured on II-80°. In addition, 1000 short tracks have been measured on II-30°, and 150 tracks corresponding to 4.5 Mev$\leq E_x\leq$5.8 Mev have been measured at 45°. The data are shown as Figs. 1–7.

A secondary scale, showing the excitation energy (E_x) of the B^{10} nucleus, has been drawn on all the data figures so that the value of the energy level corresponding to a given neutron group can be seen directly.

The same groups, some of which were quite doubtful from the original 0° and 80° data (exposure I), have been observed again at the various angles. Better values of the energies of these levels are available from a combination of the new and the old data (Table I). There is indication from the 30° data (Fig. 3) of a previously unreported group corresponding to a level at approximately 5.37 Mev. At other angles, this group, if it is real, is submerged in the low energy tail of the 5.14-Mev doublet.[10] The level at 5.58 Mev, listed as uncertain in I, apparently reappears at 30° and 45°, but its neutron groups remain low in intensity. A very "weak" level at 5.72 Mev, suggested by I, cannot be either supported or excluded on the basis of the 30° and the 45° data. The doubtful 6.38-Mev level, sug-

TABLE I. Q-values of states of B^{10}.

I-0°	II-0°	II-10°	II-30°	II-45°	I-80°	II-80°	Av. Q from present data	Other Q-values	B^{10} energy levels
+4.33	+4.40	+4.36	+4.35	+4.31	+4.29	+4.44	+4.35±0.06	+4.363±0.016[a]	0
+3.59	+3.68	+3.69	+3.66	+3.59	+3.60	+3.67	+3.64±0.06	+3.644±0.016[b]	0.72
+2.57	+2.65	+2.63	+2.61	+2.61	+2.54	+2.69	+2.61±0.06	+2.627±0.016[c]	1.74
+2.16	+2.29	+2.20	+2.20	+2.26	+2.11	+2.24	+2.21±0.06	+2.223±0.015[c]	2.15
+0.78	+0.92	+0.88	+0.75	+0.86	+0.75	+0.90	+0.83±0.06	+0.779±0.030[c]	3.58
−0.44	—	—	−0.40	−0.40	−0.43	—	−0.42±0.04		4.78
−0.76	—	—	−0.79	−0.80	−0.78	—	−0.78±0.04	{−0.752±0.016[d] {−0.805±0.016	{5.12 {5.17
—	—	—	−1.01	—	—	—	−1.01±0.04		5.37
−1.24	—	—	−1.17	−1.23	−1.22	—	−1.22±0.04		5.58
−1.35	—	—	—	−1.41	−1.33	—	−1.36±0.04		5.72
−1.55	—	—	−1.57	—	−1.58	—	−1.57±0.04	−1.566±0.017[d]	5.93
−1.73	—	—	−1.79	—	−1.77	—	−1.76±0.04		6.12
−2.03	—	—	−2.02	—	−2.00	—	−2.02±0.04		6.38
−2.22	—	—	−2.21	—	−2.22	—	−2.22±0.04		6.58
−2.45	—	—	−2.38	—	—	—	−2.41±0.04		6.77

[a] Computed from $Q=(2D-He^4)-(Q_d+Q_{dp}+Q_{d\alpha})$. The details of this computation are given in reference 5.
[b] Computed from reference a and from Craig, Donahue, and Jones, Phys. Rev. **87**, 206 (1952).
[c] Computed from reference b and from Rasmussen, Hornyak, and Lauritsen, Phys. Rev. **76**, 581 (1949); and Chao, Lauritsen, and Rasmussen, Phys. Rev. **76**, 582 (1949).
[d] Computed from references 10 and a.

[10] T. W. Bonner and J. W. Butler's work [Phys. Rev. **83**, 1091 (1951)] has indicated the existence of two levels at 5.115 and 5.168 Mev. The energy of these levels has been recalculated on the basis of the best known Q-value for the $Be^9(d,n)B^{10}$ reaction (see Table I).

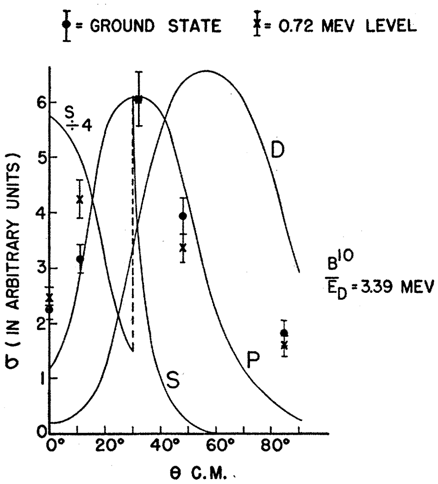

FIG. 8. Angular distributions of neutrons from the ground state and the 0.72-Mev state of B^{10} and the theoretical Butler curves.

gested by I, is well resolved, and its neutron group is fairly intense at 30° in the present exposure.

The standard deviation is 60 kev or less for the first five states of B^{10}, and 30 kev or less for the higher energy levels. The estimated uncertainty shown in Table I is based on the standard deviation and is larger than the standard deviation in the case of the high energy levels which were observed at relatively few angles.

ANALYSIS OF THE ANGULAR DISTRIBUTION DATA

One of the main reasons for exposure II was the possibility of observing the angular distributions of the neutrons from the first five states of B^{10}. It was hoped that by plotting the Butler curves for the various states, and by comparing the angular distributions with these curves, the parity of the five states could be determined.

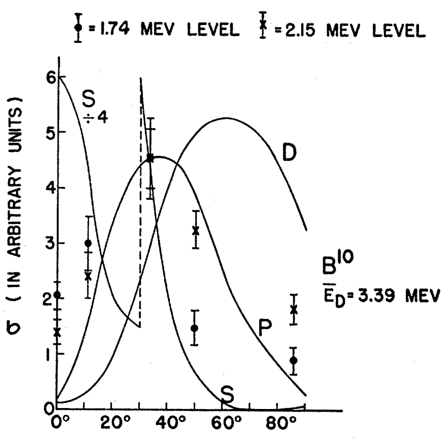

FIG. 9. Angular distributions of neutrons from the 1.74-Mev and the 2.15-Mev states and the theoretical Butler curves.

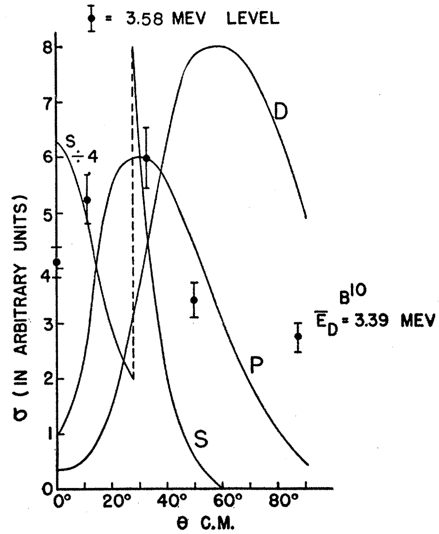

FIG. 10. Angular distributions of neutrons from the 3.58-Mev state and the Butler curves.

Equation 34 of Butler's paper[2] has been used in the calculation of the theoretical curves. "r_0" has been taken to be 4.53×10^{-13} cm by appropriate substitution in the formula

$$r_0 = 1.47\times10^{-13}(A^{\frac{1}{3}}+1) \text{ cm}.$$

To test the sensitivity of shape to choice of r_0, some curves were also calculated for a 20 percent larger r_0. The shape was qualitatively unaffected, and the peaks were shifted to smaller angles by only a few degrees. Such a small shift is not sufficient to lead to confusion as to which curve best fits given experimental data.

No attempt has been made to evaluate any of the constant multiplicative factors in Butler's equation. The ordinates in Figs. 8–12 are therefore arbitrary, but the units used are the same for all the figures.

The "shape" of the experimental points determines the choice of the Butler curve which best fits it. The ordinate scale was then adjusted so that the maximum

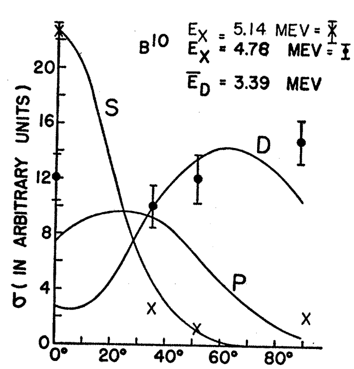

FIG. 11. Angular distributions of neutrons from the 4.78-Mev state and the 5.14-Mev doublet and the Butler curves.

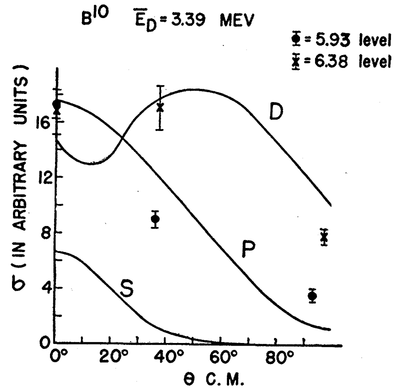

FIG. 12. Angular distributions of neutrons from the 5.93-Mev and the 6.38-Mev states and the Butler curves.

of the theoretical curve coincided with the highest experimental point.

Since the ground state of Be^9 is believed to have odd parity, then, because of conservation of parity, the angular distributions of the neutrons fix the parity of the final states in B^{10} as odd or even, depending upon whether the angular momentum transfer is even or odd.

Figures 8, 9, and 10 show the Butler curves as well as the experimental points for the ground state, and for the 0.72, 1.74, 2.15, and 3.58 Mev levels (data from both exposure I and exposure II are incorporated in the points). All these points fit the corresponding $P(l_p=1)$ curve which means that these B^{10} levels are of even parity. Table II shows the relative number of neutrons per unit solid angle as a function of angle. It also indicates the relative total cross section for each level.

An attempt was also made to ascertain the parity of some of the higher energy levels. Measurements of the neutrons from the 4.78-Mev level have been carried out at I–0°, II–30°, II–45°, and I–80°. Figure 11 shows the corresponding Butler curves and the experimental points. These points do not seem to fit any one of the curves. Some possible explanations are: (1) Compound nucleus formation may be more likely than stripping. (2) There may be two closely spaced levels which were not resolved in the neutron work. (3) A combination of the $l_p=0$ and $l_p=2$ distributions may have been observed. If this is the correct explanation, then the parity is fixed as odd and the J is either 1 or 2.

TABLE II. Relative number of neutrons from the first five states of B^{10}.

Angle	0	0.72	1.74	2.15	3.58
	E_x of B^{10} (Mev)				
0°	5.2	5.7	1.6	1.6	4.6
10°	7.4	9.7	2.7	2.4	6.0
30°	14.1	13.8	3.4	5.2	6.9
45°	9.1	7.7	1.5	3.3	3.9
80°	4.2	3.7	0.7	2.1	3.2
Relative total cross section	4.4	4.1	0.9	1.7	2.3

It was also decided to plot the angular distribution of the neutrons from the 5.14-Mev doublet. At 0°, 45°, and 80°, the data may include some neutrons from an unresolved 5.37-Mev level, but these neutrons should be comparatively few and should thus not bring in an appreciable error. Figure 11 shows the results. It is immediately obvious that at least one, and probably both, of the levels in the doublet are formed by s-wave proton capture ($l_p=0$) and hence have $J=1$ or 2 and odd parity. In fact, the strong forward neutron bunching associated with s-wave proton capture is probably the reason Bonner and Butler[10] see both members of the doublet by their neutron threshold technique but do not see the 4.78-Mev level, for instance, as a neutron threshold.

It was not possible to resolve completely any of the other high energy levels except, possibly, the 5.93- and the 6.38-Mev levels which were observed at I–0°, II–30°, and I–80°. Figure 12 shows the Butler curves and the experimental points for both levels. The 5.93-Mev level points could fit either the S or the P curve, and therefore nothing can be said about the parity of this state. The 6.38-Mev level seems, perhaps, to fit the D curve, and thus it may be of odd parity.

TABLE III. Spins and parities of states of B^{10}.

E_x of B^{10} (Mev)	Butler spin limits	Parity	Probable spins[a]
0	0, 1, 2, 3	even	3[b]
0.72	0, 1, 2, 3	even	1
1.74	0, 1, 2, 3	even	0
2.15	0, 1, 2, 3	even	1
3.58	0, 1, 2, 3	even	2
4.78	? (see text)	?	0, 1, 2
5.14(d)	1, 2	odd	
5.93	0, 1, 2, 3	?	
6.38	0, 3, 4	odd	

[a] See reference 12.
[b] Spin measured by Gordy, Ring, and Burg, Phys. Rev. **74**, 1191 (1948).

While it is not possible to make unique spin assignments on the basis of Butler's theory since the spin of the target nucleus Be^9 is $\frac{3}{2}$,[11] conservation of angular momentum places limits on the maximum and minimum angular momentum available to the final state. For protons of orbital angular momentum l_p which are captured, these limits are

$$|\bar{J}+\bar{j}+\bar{s}_p|_{\min}\leq l_p\leq J+j+s_p,$$

where J is the spin of the final state, j is the spin of the target nucleus, and s_p is the spin of the captured proton. Table III shows these spin limits as well as guesses of the most probable spin value whenever possible. These suggestions (made by Richards[12]) are

[11] N. A. Schuster and G. E. Pake, Phys. Rev. **81**, 886 (1951).
[12] H. T. Richards, unpublished University of Pittsburgh conference on Medium-Energy Nuclear Physics, June, 1952.

based on the known gamma-ray intensities and on the known allowed gamma-ray transitions[13] as well as on beta-decay evidence.

El-Bedewi[14] has interpreted his data on the angular distributions of the protons from the $Be^9(d,p)Be^{10}$ reaction as showing that the first excited state of Be^{10} at 3.37 Mev is of even parity. It is not clear that his results exclude the possibility of this state being of odd parity. If the 3.37-Mev level in Be^{10} is of even parity, then an analogous state in B^{10} (which should appear at about 5.1 Mev) has not been observed unless the corresponding state in B^{10} has been greatly shifted in energy. It would be extremely useful if the question of the parity of the 3.37-Mev state in Be^{10} were reinvestigated.

EXPERIMENTAL PROCEDURE AND RESULTS—(*d,p*) EXPOSURE

Dr. R. Sherr of Princeton University suggested to the author that perhaps the 413.5-kev gamma-ray observed[13] when Be^9 is bombarded with deuterons might be due not to a cascade transition in B^{10} but

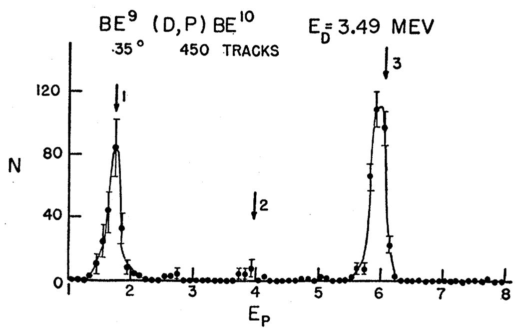

FIG. 13. $Be^9(d,p)Be^{10}$ data at 35°. N is the number of protons/100-kev interval.

instead to a level at approximately 0.4 Mev in Be^{10}, a level which would therefore be analogous to the 2.15-Mev level in B^{10}. Other investigators have previously covered this region in Be^{10}, but the work was performed either with fairly poor resolution[14,15] or with good resolution but with a fairly intense alpha-group appearing in the region where the possible 0.4-Mev level group might have been observed,[16] and the alpha-group might possibly have concealed it. Therefore, it was deemed advisable to test Dr. Sherr's hypothesis by observing the $Be^9(d,p)Be^{10}$ reaction again under favorable conditions.

The protons emitted at 35°±2° in the laboratory system were observed by means of a 100-micron NTA

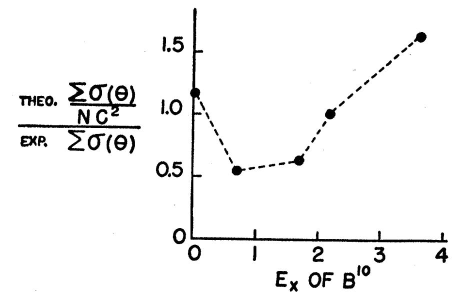

FIG. 14. Plot of the ratio of the integrated Butler equations for the $l_p=1$ cases, with the nuclear factors considered constant, to the relative total experimental cross sections for the first five states of B^{10}.

plate.[17] The number N of protons per 100-kev interval was then plotted against the proton energy. Figure 13 shows the data.

If the ground state of Be^{10} is analogous to the 1.74-Mev level of B^{10}, we know that it must have the same parity, and therefore its maximum yield should occur at the same angle (about 35° in the laboratory system). Similarly, if there is a state of Be^{10} at 0.4 Mev, its maximum yield should likewise be at that same angle. This is why the exposure was made at 35°.

The ground state and the known excited state at 3.37 Mev have been observed. The corresponding proton groups are indicated as "3" and "1," respectively, on Fig. 13. The group indicated as "2" is of the correct energy to be due to protons from the $C^{12}(d,p)C^{13}$ reaction. There is no indication of a group corresponding to a 0.4-Mev state in Be^{10} of intensity greater than 5 percent of the intensity of the ground-state group. From charge independence considerations and from the corresponding angular distributions in B^{10}, one would expect the 0.4-Mev level in Be^{10}, if it exists, to have an intensity comparable in magnitude to the intensity of the proton group from the ground state. The fact that there is no such intense group seems to be extremely strong evidence that there is no level in Be^{10} at 0.4 Mev and that the 413.5-kev gamma must be fitted into the Be^{10} level scheme.

DISCUSSION AND ACKNOWLEDGMENTS

Buechner's group at M.I.T.[18] have studied the inelastic scattering of 7-Mev protons from B^{10}. Their results confirm the existence of the first five excited states of B^{10} observed in this investigation.

Schecter[19] has bombarded Be^9 with 20-Mev deuterons and has observed the angular distributions of the neutrons by the method of foil activity. He assumed that all the neutrons he observed derived from the

[13] See reference c in Table I.
[14] F. A. El-Bedewi, Proc. Phys. Soc. (London) **A65**, 64 (1952).
[15] Lattes, Fowler, and Cuer, Proc. Phys. Soc. (London) **59**, 883 (1947), and others.
[16] Strait, Van Patter, Buechner, and Sperduto, Phys. Rev. **81**, 747 (1951).
[17] The details of the experimental arrangement and procedure are discussed in the author's doctoral dissertation: Fay Ajzenberg, unpublished PhD thesis, University of Wisconsin (1952).
[18] Buechner, Browne, Elkind, Sperduto, and Bockelman, Phys. Rev. **87**, 237A (1952).
[19] L. Schecter, Phys. Rev. **83**, 695 (1951).

ground state of B^{10}, and he concluded from the shape of the distribution that the ground state is of even parity. Actually Schecter was observing the first four or five states of B^{10}, but his conclusion was not incorrect since apparently all these states are of even parity and therefore have the same characteristic distribution.

Throughout this paper, the Butler curves have been drawn neglecting the spin factor $(2J+1)/[(2s_p+1)\times(2j+1)]$ in Eq. 34 of Butler's paper.[2] It was decided to assume spins of 3, 1, 0, 1, and 2, respectively, for the first five states of B^{10} and to plot the ratio of the integrated Butler equations for the $l_p=1$ cases, with the nuclear factors considered constant, to the relative total experimental cross sections. Figure 14 indicates that if the assumed spin assignments were correct, then the nuclear factors affecting the stripping process are constant within a factor of about 3 for these states.

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The Energy Spectrum of Positrons from the Decay of the μ-Meson*

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The energy of the positrons from 301 $\pi\rightarrow\mu\rightarrow\beta$ decays have been determined in electron sensitive emulsions by measuring the multiple scattering of the positron tracks. The annihilation properties of the charged particle emitted in the decay of the μ^+ meson confirm its identity as a positron. This spectrum has a maximum about 36 Mev and a nonzero cutoff at the high energy end. A statistical analysis of the data, using the Michel theory, yields a value of $\rho=0.41\pm0.13$.

I. INTRODUCTION

Earlier experiments[1] have demonstrated that the β-decay of the μ-meson is consistent with the scheme

$$\mu\rightarrow\beta+\nu+\nu. \quad (1)$$

However, the possibility that β-decay of the μ-meson might be merely one phase of a universal interaction between fermions has raised interest in the exact shape of the spectrum of the β-particle. It is here that previous experiments have given contradictory results, due either to poor energy resolution of individual β-particles, to the low number of such events obtained, or both. A brief report on the preliminary results of our measurements has been given previously.[2]

II. METHOD

A. Detector

Minimum ionization emulsions were used to detect the $\pi\rightarrow\mu\rightarrow\beta$ decay. Emulsions have several important advantages in a study of the β-decay of the μ-meson. The grain density for all β's of relativistic energies is substantially the same;[3] hence, all decay β's are recorded with virtually equal sensitivity. Whereas it is characteristic of other methods of detection that massive material is used to stop the μ-meson and the decay β observed only after emergence from this "dead mass," the β-track is unobscured at any stage when emulsions are employed. Emulsions are also able to be used inside the 381-Mev Nevis cyclotron, where the meson flux is such that even in restricting entrance to the emulsion to pions of an 11- to 14-Mev band and less than a $\pm10°$ spread, some 10^4 pions/sec/cm^3 of emulsion are obtained.

Problems peculiar to the photographic technique for this purpose include the substantial labor required for high energy resolution per track through multiple scattering measurements, the discrimination against low energy β's because of outscattering from an emulsion of finite depth, and the necessity to obtain an accurate calibration of energy with multiple scattering measurements. As with other techniques, the uncertainty in energy degradation must be evaluated. These points will be discussed in greater detail below.

B. Multiple Scattering Measurements

The technique of determining the energy of a fast particle through the average magnitude of Coulomb scatterings in emulsion has been analyzed by Gold-

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