The present investigation also reveals possible levels at 4.95 ± 0.02 and 6.50 ± 0.09 Mev in F^{19}. The groups belonging to these levels however, were not sufficiently well defined to allow their identification through the shift in range with angle. Each of these levels was observed at only three of the eight angles studied.

ACKNOWLEDGMENTS

The authors wish to thank Dr. D. J. Prowse of Bristol University, England, for lending them the plates and carrying out the exposure with the Birmingham group and also for sending the scan-sheets of the initial work done in Bristol.

PHYSICAL REVIEW VOLUME 108, NUMBER 2 OCTOBER 15, 1957

Gamma Rays from the Reactions $F^{19}(p,\alpha\gamma)O^{16}$, $Be^9(d,p\gamma)Be^{10}$, $Be^9(d,n\gamma)B^{10}$, $B^{10}(p,p'\gamma)B^{10}$, and $B^{11}(p,p'\gamma)B^{11}$†

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The Rice Institute magnetic-lens pair spectrometer has been used to detect γ radiation from the $F^{19}(p,\alpha)O^{16*}$ reaction. The γ-ray transition from the 8.88-Mev level in O^{16} to the ground state and the cascade γ from this level to the 6.13-Mev state have been observed. Relative intensities of these γ rays and the 7.12-Mev γ ray are given. Gamma-ray spectra from Be^9+d were observed at 1.5-, 2.0-, 3.2-, and 4.0-Mev deuteron energies. Relative intensities of the 2.90-, 3.38-, 4.45-, and 5.99-Mev γ radiation were determined. Excitation curves were obtained for the 3.38- and 5.99-Mev γ rays from Be^{10*} between deuteron energies of 1.0 and 5.6 Mev. The relative intensities of the 3.58- and 2.86-Mev radiations from the 3.58-Mev level in B^{10*} were measured using the $B^{10}(p,p')B^{10*}$ reaction. Other γ radiation with energies of 0.43 Mev from $B^{10}(p,\alpha)Be^{7*}$, 0.72, 1.023, and 1.438 Mev from $B^{10}(p,p')B^{10*}$, and 2.134 Mev from $B^{11}(p,p')B^{11*}$ was observed.

INTRODUCTION

THE magnetic-lens pair spectrometer used in the work reported in this paper is described in other papers.[1,2] Measurements of γ-ray energies with this spectrometer from the $F^{19}+p$ and Be^9+d reactions have been reported on previously.[1,3] In the present experiments the spectrometer was used with a higher transmission and a lower energy resolution of 7%. Under these conditions the background due to chance coincidences and scattered radiation is materially reduced in comparison to the number of true coincidences and so weaker γ radiation may be observed.

$F^{19}(p,\alpha)O^{16*}$

Recent work by several groups[4–7] shows the existence of a state in O^{16} at 8.88 Mev. Wilkinson *et al.*,[4] observed cascade γ rays from this state to the 6.14-, 6.91-, and 7.12-Mev levels but did not detect the ground-state transition. Hornyak and Sherr[5] observed inelastically scattered protons from the 8.88-Mev state in the reaction $O^{16}(p,p')O^{16*}$. Alpha particles to the 8.88-Mev level in the reaction $F^{19}(p,\alpha)O^{16*}$ have been observed by Squires *et al.*,[6] and Young *et al.*[7] The γ radiation from $F^{19}+p$ has been studied previously in this laboratory[1] and the results indicated no lines between 7.5 and 11.0 Mev with an intensity greater than 10% that of the 7-Mev radiation.

Because weaker radiation could be detected with the higher transmission of the present instrument, a search was made for the 8.88-Mev γ ray which had not been observed. Since the spectrometer is much more sensitive to nuclear pairs than to γ rays, a proton energy was used at which the ratio of γ intensity to nuclear pair intensity was highest, in order to keep the γ-ray counting rate as high as possible in comparison with the background counting rate contributed by the nuclear pairs from the 6.053 state of O^{16}. From the γ-ray and nuclear pair excitation curves[2] it was found that a suitable bombarding energy was 4.25 Mev, taking into account the necessity of a high bombarding energy in order to strongly populate the 8.88-Mev level which is formed in the reaction $F^{19}(p,\alpha)O^{16*}$ with a Q value of -0.752 Mev. The target used was 1.58 mg/cm² CaF_2 evaporated on a 11.8-mg/cm² Ag foil. The experimental results are shown in Fig. 1. The spectrum has been corrected for background effects in the regions of the 2.80-, 7.10-, and 8.91-Mev peaks. At the 2.80-Mev peak a background counting rate (chance plus zero field true coincidences) equal to 11% of the actual counting rate has been subtracted from the original data. A background rate of 6% of the counting rate at

† Supported in part by the U. S. Atomic Energy Commission.
[1] Bent, Bonner, and Sippel, Phys. Rev. **98**, 1237 (1955).
[2] Ranken, Bonner, and McCrary (to be published).
[3] Bent, Bonner, McCrary, Ranken, and Sippel, Phys. Rev. **99**, 710 (1955).
[4] Wilkinson, Toppel, and Alburger, Phys. Rev. **101**, 673 (1955).
[5] W. F. Hornyak and R. Sherr, Phys. Rev. **100**, 1409 (1955).
[6] Squires, Bockelman, and Buechner, Phys. Rev. **104**, 413 (1956).
[7] Young, Phillips, and Spencer, Phys. Rev. **108**, 72 (1957).

the 7.1-Mev peak and of 70% of the counting rate at the 8.91-Mev peak has been subtracted. In addition to the very intense peak due to nuclear pairs, peaks were found at 2.80±0.04 Mev, 7.10±0.04 Mev, and 8.91±0.05 Mev (uncorrected for Doppler effects). The Doppler-corrected energies of the γ rays and their relative intensities are given in Table I. Since the 2.79-Mev γ ray is considerably more intense than the 8.88-Mev radiation the life time of the 8.88-Mev state will be approximately the time for emission of the 2.79-Mev radiation. The calculated value of this lifetime is 10^{-15} second based on the single-particle-model transition probability. Since the radiating nucleus loses little of its velocity in this time, the full Doppler correction to the γ-ray energies has been made.

In order to de-excite by γ radiation rather than by α-particle emission the spin and parity of the 8.88-Mev state must be 1+, 2−, 3+, $\cdots$. The first possibility would result in low multipole radiation to the 0+ ground state and higher multipole radiation to the

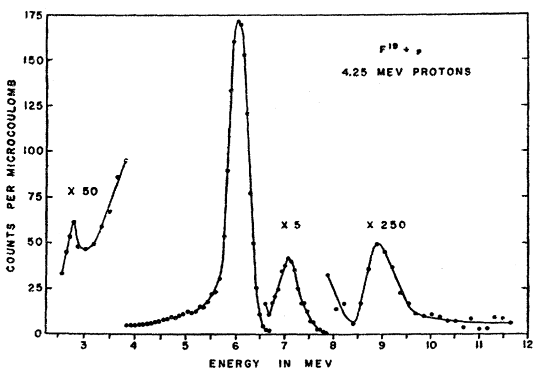

FIG. 1. Internal and nuclear pair spectrum from excited states of O^{16} produced by the bombardment of a 1.58-mg/cm² CaF_2 target with 4.25-Mev protons.

6.14-Mev 3− state. This would result in the ground state transition being more intense than the cascade. This leaves only 2− or 3+ as plausible assignments to the level.

Wilkinson *et al.*,[4] were not able to detect the 8.88-Mev γ ray but reported that with 4.1-Mev protons the γ ray was less than 15% as intense as the 2.8-Mev cascade. In the present experiment the ratio of the number of 8.88- to 2.79-Mev γ's was found to be 0.09±0.04. The theoretical γ-ray branching ratios for a 2− and for a 3+ assignment to the 8.88-Mev level, using the single particle model, are given in Table I. The experimental results agree with the 2− assignment and disagree with the 3+ assignment by a factor of 10^4. The results are also in good agreement with branching ratio calculations made by Flowers and Elliott[8] using the intermediate coupling theory based on an assignment of 2− to the 8.88-Mev level. A conservative conclusion is that the state at 8.88 Mev is a 2− level.

[8] B. H. Flowers and J. P. Elliott (private communication).

TABLE I. Doppler corrected energies and relative intensities of γ rays from the $F^{19}(p,\alpha)O^{16*}$ reaction.

γ energy (Mev)	Relative peak height	Type radiation	Relative spec-trometer efficiency	Relative intensity	Theoretical intensity if 8.88 Mev state is 2−	3+
2.79	5.8	*M*1 or *E*1	0.26	1.00		
7.08	100	*E*1	1.00	4.5		
8.88	2.0	*M*2 or *E*3	1.05	0.09	0.07	10^{-5}

$Be^9(d,p)Be^{10*}$, $Q=4.59$ Mev; $Be^9(d,n)B^{10*}$, $Q=4.36$ Mev

Previous γ-ray spectra from the bombardment of beryllium by deuterons were obtained by Bent *et al.*,[3] who observed γ radiation above 4 Mev. With the greater efficiency of the spectrometer used in the present experiments, it was possible to study lower energy γ radiation as well as that above 4 Mev.

Spectra were obtained at deuteron energies of 1.5, 2.0, 3.2, and 4.0 Mev using a 25.3 mg/cm² Be metal disk as a target. This target is sufficiently thick to stop the deuterons of all energies used. Results of the experiments are shown in Fig. 2. These curves have

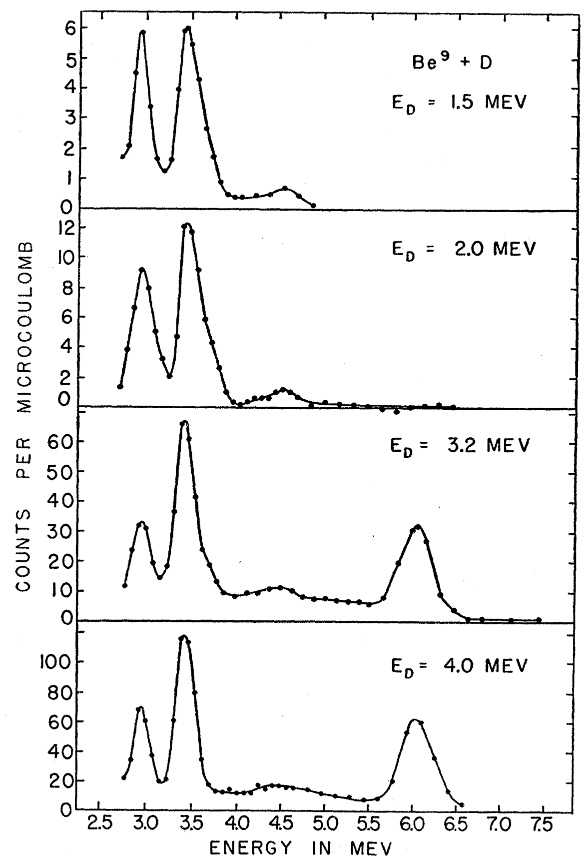

FIG. 2. Internal pair spectra from excited state of B^{10} and Be^{10} from the bombardment of a 25.3-mg/cm² Be^9 target with deuterons of 1.5, 2.0, 3.2, and 4.0 Mev.

TABLE II. Energies and relative intensities of γ rays from the bombardment of Be^9 with deuterons.

Deuteron energy (Mev)	γ-ray energy (Mev)	Relative peak height	Type radiation	Relative spectrometer efficiency	Relative intensity
	2.89	12.7	$M1$	0.67	19
1.5	3.40	12.9	$E2$	1.0	13
	4.49	1.4	$M1$	1.3	1.1
	2.92	19.6	$M1$	0.67	29
2.0	3.40	26.4	$E2$	1.0	26
	4.49	2.6	$M1$	1.3	2.0
	2.93	71	$M1$	0.67	106
3.2	3.40	143	$E2$	1.0	143
	4.48	24	$M1$	1.3	17.5
	6.04[a]	68	$M1$	1.7	40
			$E1$	2.1	32
	2.92	150	$M1$	0.67	220
4.0	3.40	252	$E2$	1.0	252
	4.47	37	$M1$	1.3	28
	6.03	134	$M1$	1.7	79
			$E1$	2.1	64

[a] The spin of the 5.96 level in Be^{10} is not known and other type γ transitions besides $M1$ and $E1$ are possible.

been corrected for chance and zero field counting rates which amounted to 25% of the total counting rate at the 3.40-Mev peak and 10% of the 6.04-Mev peak on the $E_d = 4$-Mev curve. Table II gives the relative intensities of the γ radiation taken at the different bombarding energies.

The mean γ-ray energies, the Doppler corrected energies, and the assignment of the radiations are shown in Table III.

Figure 3 shows the energy level diagrams of Be^{10} and B^{10}. Spin assignments of the 4.77-, 5.11-, and 5.16-Mev levels in B^{10} are due to Hanna and Meyer-Schützmeister.[9] Life time calculations indicate that Doppler corrections should be made on the 2.92-, 4.48-, and 6.04-Mev γ rays as indicated in the second column of Table III. The mean life of the 3.37-Mev level in Be^{10}, which decays by $E2$ radiation, has a calculated value of 10^{-12} second on the single-particle model. On this basis no Doppler shift should be found. The measured γ-ray energy of 3.40 ± 0.03 Mev indicates that there may be a Doppler shift which is only possible if the life time of the state is approximately 5 times shorter than that predicted on the single particle model. An enhancement in the $E2$ transition probability of an even larger amount is possible where collective motions are important.

Since the 2.92-Mev peak is approximately half way between the expected γ rays at 3.01 and 2.86 Mev (5.16- to 2.15-Mev cascade and 3.58- to 0.72-Mev cascade, respectively), it could be due to either of these or to the unresolved peak resulting from the presence of both γ rays. γ radiation of 3.58 Mev produces a noticeable broadening on the high side of the 3.40-Mev γ-ray peak and indicates the presence of some ground

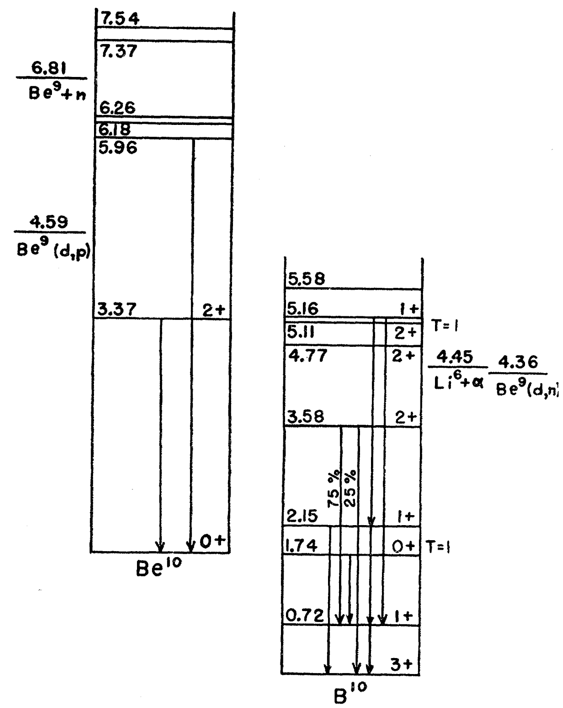

FIG. 3. Energy level diagrams for Be^{10} and B^{10} showing the γ transitions observed in the present experiments. (Energies in Mev.)

state γ radiation from the 3.58-Mev level in B^{10}. The 5.16-Mev γ from B^{10} was not resolved in the present experiment and it appears to be considerably weaker than the cascade γ ray of 4.48 Mev. This agrees with the result of Wilkinson and Jones[10] that the $5.16 \rightarrow 0.72$ Mev cascade in B^{10} is about 5 times stronger than the 5.16-Mev ground state transition. The γ radiations from $Be^9 + d$ have also been studied by Rasmussen, Hornyak, and Lauritsen[11]; Chao, Lauritsen, and Rasmussen[12]; and Shafroth and Hanna.[13] The earlier

TABLE III. Energies and assignments of γ rays from the bombardment of Be^9 with deuterons.

Uncorrected energy (Mev)	Doppler corrected energy (Mev)	Assignment (level energies in Mev)
2.92 ± 0.03[a]	2.90 ± 0.03	B^{10} ($3.58 \rightarrow 0.72$)
		B^{10} ($5.16 \rightarrow 2.15$)
3.40 ± 0.03	3.38 ± 0.03	Be^{10} (3.37)
4.48 ± 0.05	4.45 ± 0.05	B^{10} ($5.16 \rightarrow 0.72$)
6.035 ± 0.04	5.985 ± 0.04	Be^{10} (5.96)

[a] At the higher deuteron energies used there is also a possible contribution due to the 6.26 Mev→3.37 Mev cascade in Be^{10}.

[9] S. S. Hanna and L. Meyer-Schützmeister, Bull. Am. Phys. Soc. Ser. II, **2**, 180 (1957). Level assignments are those given orally and differ from those suggested in the abstract.

[10] D. H. Wilkinson and G. A. Jones, Phys. Rev. **91**, 1575 (1953).

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

[12] Chao, Lauritsen, and Rasmussen, Phys. Rev. **76**, 582 (1949).

[13] S. M. Shafroth and S. S. Hanna, Phys. Rev. **95**, 86 (1954).

experiments were all made with deuterons of 1.5 Mev or less. Relative intensities given in references 11 and 12, taken at 1.2- and 1.5-Mev deuteron energy respectively, are in fairly good agreement with the present 1.5-Mev results. At higher bombarding energies the 6-Mev radiation, which results from the (d,p) reaction with a Q value of -1.37 Mev, increases rapidly in intensity. There is also some increase in the strength of the 3.4-Mev radiation [(d,p) reaction] as compared with the sum of the contributions from the 2.86- and 3.01-Mev γ rays [(d,n) reaction] with increasing deuteron energy. The relative change in intensities with increasing deuteron energy is opposite to that expected from the stripping theory where the effect of the barrier penetration on the (d,n) reaction results in a greater increase in cross section than in the case of the (d,p) reaction. From the statistical point of view there are only two levels in Be^{10} that are populated with 1.5-Mev deuterons while at a deuteron energy of 4 Mev there are seven or more levels which compete. In contrast, at a deuteron energy of 1.5 Mev there are nine levels in B^{10} which are populated and this number increases to eighteen levels with 4-Mev

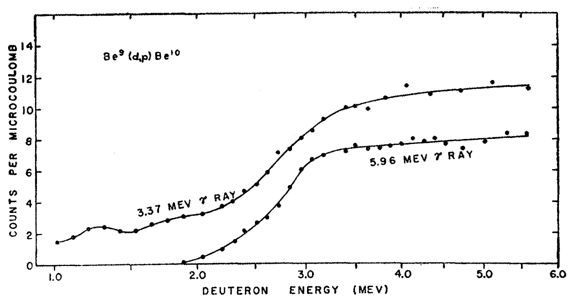

FIG. 4. Excitation functions of the 3.37-Mev and 5.96-Mev γ rays from the $Be^9(d,p)Be^{10*}$ reaction.

deuterons. On the basis of this statistical argument the relative intensities of the 3.4- and 2.92-Mev γ radiation should have changed in the opposite way to that observed.

Excitation functions of the 3.37- and 5.96-Mev γ radiation from the (d,p) reaction in Be^9 were measured in another experiment using a thin beryllium target (0.62 mg/cm^2). The results are given in Fig. 4. The Q values for the two groups of protons that give rise to these γ rays are $+1.22$ and -1.37 Mev. The yield of 5.96-Mev γ rays rises rapidly above the threshold at 1.37 Mev and then becomes nearly constant above 3 Mev. The yield of 3.37-Mev γ radiation shows a broad resonance at 1.3 Mev and a possible resonance at about 1.8 Mev. The intensity increases rapidly at approximately 2.6 Mev and becomes nearly constant above 4 Mev. Cavanan[14] has observed a broad resonance at 2.1 Mev in the yield of long range protons from the reaction $Be^9(d,p)Be^{10}$. The slight indication of a resonance around 1.8 Mev in the present work may be due

[14] F. L. Cavanan, Phys. Rev. **87**, 136 (1952).

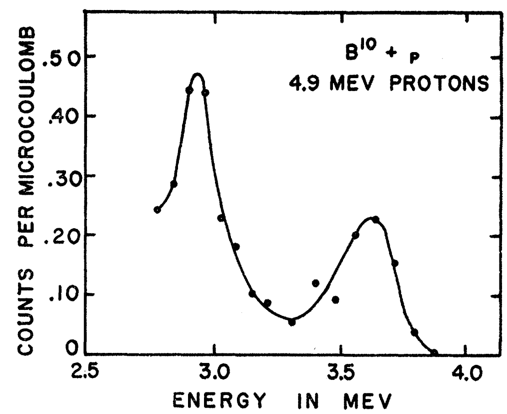

FIG. 5. Internal pair spectrum from excited states of B^{10} from the bombardment of a 15-mg/cm^2, 96% B^{10} target with 4.9-Mev protons.

to the same level in the compound nucleus. The results of earlier experiments of Evans, Malich, and Risser[15] indicate a broad resonance at about 1 Mev in the yield of γ radiation and neutrons from the deuteron bombardment of Be^9.

$B^{10}(p,p')B^{10*}$

In order to obtain better information about the γ-ray branching ratios from the states in B^{10}, measurements were made of the relative intensities of γ rays occurring in the reaction $B^{10}(p,p')B^{10*}$. In this experiment it was possible to excite each level individually and observe rather weak transitions since the background was low.

Protons with an energy of 4.9 Mev were used to populate the 3.58-Mev level in B^{10}. The resulting γ spectrum was observed in the γ-ray energy range of 2.6 to 3.8 Mev. The target consisted of 96% B^{10}, 15 mg/cm^2 thick, pressed on 22.5 mg/cm^2 nickel (0.001 in.). Figure 5 shows the results of the experiment, corrected for chance and zero field counting rates. Table IV gives the γ-ray energies and relative intensities. A Dopplet correction of 20 kev has been applied to both γ rays. The cascade γ ray is approximately three times as intense as the 3.58-Mev radiation to the ground state. Since both of the radiations are of the $M1$ type, the higher energy transition should be stronger by a factor of two because of the E^3 relation. The results indicate a

TABLE IV. Energies, relative intensities, and assignment of γ rays from the reaction $B^{10}(p,p')B^{10*}$.

Doppler corrected energy (Mev)	Type radiation	Assignment	Experimental relative intensity	Theoretical relative intensities $a/K=3.0$	$a/K=4.5$
2.87 ± 0.04	$M1$	B^{10} ($3.58\rightarrow0.72$)	2.9	0.67	0.5
3.56 ± 0.05	$M1$	B^{10} ($3.58\rightarrow0$)	1	1	1

[15] Evans, Malich, and Risser, Phys. Rev. **75**, 1161 (1949).

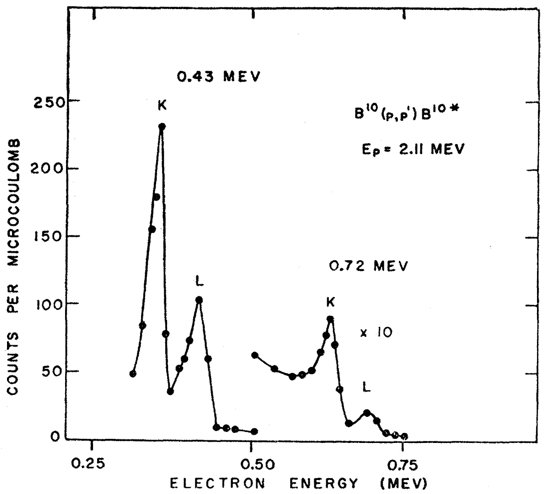

FIG. 6. Photoelectron spectrum from the bombardment of a 49 mg/cm², 96% B^{10} target with 2.11-Mev protons (14-mg/cm² Au radiator).

hindrance factor of six for the 3.58-Mev ground state transition relative to the cascade transition.

The intermediate coupling theory of Kurath[16] has been quite successful for calculating the energy levels for nuclei in the region of filling the $1p$ shell. The theory has been extended further[17] to calculate the branching ratios for the 5.16-, 3.58-, and 2.15-Mev levels in B^{10}. Branching ratios have been calculated for two values of the parameter a/K (the relative strength of the spin-orbit coupling) which lie in the region where the calculated level scheme resembles the experimental one, *viz.*, $a/K=3.0$ and 4.5. The theoretical values for the relative intensity of the 3.58→0.72 and 3.58→0 Mev γ rays are given in Table IV along with the experimental values. The agreement between the experimental and theoretical results is not good.

The γ rays from the 2.15- and 1.74-Mev levels in B^{10} are not energetic enough to be observed with the pair spectrometer. In order to study the γ radiation from these states, the pair detection system was replaced by a single scintillation counter and the instrument was used as a β-ray spectrometer to observe photoelectrons produced in a heavy metal radiator. This arrangement of the spectrometer gave a momentum resolution of 2.3% for the internal conversion electrons associated with the 1.066-Mev γ ray from a Bi^{207} source.

The γ-ray spectrum arising from the bombardment of a 49-mg/cm², 96% B^{10} target with 2.11-Mev protons was observed in the energy region of 0.25 to 0.85 Mev. The radiator was a gold foil with a thickness of 14 mg/cm². At this proton energy it is possible to excite only the 0.72-Mev and 1.74-Mev levels in B^{10}. The spectrum is shown in Fig. 6. The peak at 0.43 Mev is assigned to the 0.43-Mev level in Be^7 which is produced in the reaction $B^{10}(p,\alpha)Be^7$ with a Q value of 1.148 Mev. The 0.72-Mev γ ray from B^{10} is weaker than the 0.43-Mev γ ray from Be^7 by a factor of 32. This ratio was obtained from the L conversion line of the 0.43-Mev radiation, since there was considerable loss of counts from the lower energy K conversion electrons.

γ-ray spectra were also obtained for proton energies of 3.58 and 4.5 Mev. These measurements were made with an 18-mg/cm² thick B^{10} target (96% B^{10}) pressed onto a thorium radiator 37 mg/cm² in thickness. At a proton energy of 3.58 Mev it is possible to excite only the 0.72-, 1.74-, and 2.15-Mev levels in B^{10}. Figure 7 shows the γ radiations which were observed. The energy scale has been adjusted so that the K peaks represent the full γ-ray energy. The 1.368±0.001 Mev γ ray[18] from the $Al^{27}(p,\alpha)Mg^{24}$ reaction was used to calibrate the spectrometer. Measurements of the life time of the 1.368-Mev state in Mg^{24} [19] indicate no Doppler shift occurs. At 3.58-Mev bombarding energy, γ rays were observed with energies of 1.02, 1.43, and 2.14 Mev. The 1.02-Mev line is assigned to the 1.74→0.72 Mev

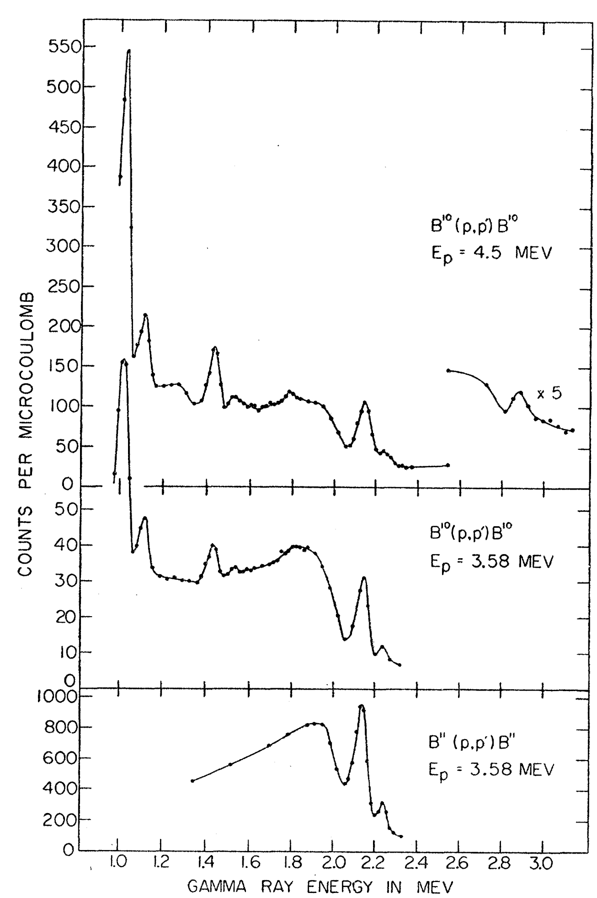

FIG. 7. Photo-electron spectra from the bombardment of an 18-mg/cm², 96% B^{10} target with 3.58- and 4.5-Mev protons and of a 15-mg/cm² natural boron target with 3.58-Mev protons (37-mg/cm² Th radiator).

[16] D. Kurath, Phys. Rev. **101**, 216 (1956).
[17] D. Kurath, Phys. Rev. **106**, 975 (1957).
[18] A. Hedgran and D. Lind, Arkiv Fysik **5**, 177 (1952).
[19] C. F. Coleman, Phil. Mag. **46**, 1135 (1955).

transition and the 1.43-Mev γ is assigned to the 2.15→0.72 Mev transition.

The presence of the strong peak at 2.15 Mev suggests that a good value of the relative intensities of the 2.15→0.72 and 2.15→0 Mev transitions should be readily obtainable. However, the first excited state of B^{11} occurs at 2.14 Mev. The possibility that 4% of B^{11}, in the nominally B^{10} target, might account for part of the observed intensity of the 2.14-Mev γ ray was tested by bombarding a natural boron (81.2% B^{11}) target with protons of 3.58-Mev energy. The thorium radiator thickness was again 37 mg/cm^2 and target thickness was 15 mg/cm^2. The results of this experiment are also shown in Fig. 7. The intensity of the 2.14-Mev radiation from B^{11} was such that essentially all of the 2.14-Mev peak obtained with the 96% B^{10} target can be ascribed to the residual 4% of B^{11}. The nature of the experiment is such that the only safe conclusion that can be drawn is that the intensity of the 2.15→0 Mev transition in B^{10} is probably less than the intensity of the 2.15→0.72 Mev transition. This rough estimate does not conflict with that of Ajzenberg and Lauritsen.[20] Their estimate is based on the work of Shafroth and Hanna,[13] who studied the B^{10} γ rays using the $Be^9(d,n)B^{10}$ reaction, where it is possible to get 1.43-Mev γ radiation from two separate cascades (3.58→2.15 and 2.15→0.72 Mev).

The γ-ray spectrum obtained from the $B^{10}(p,p')B^{10*}$ reaction when the bombarding proton energy was increased to 4.5 Mev is shown at the top of Fig. 7. The target and radiator are the same ones used to obtain the spectrum at 3.58 Mev. The intensities of the 1.02- and the 1.43-Mev γ rays have both increased by a factor of 8. The peak which is observed at 1.78 Mev is from silicon which is present as an impurity in the B^{10} target in the amount of 1%. The ease with which small amounts of B^{11}, and particularly of silicon, are detected is further indication of the small value of the $B^{10}(p,p')B^{10*}$ cross section.

No γ radiation from the 1.74 level of B^{10} to the ground state was observed. This fact places an upper limit of 7% on the intensity of the ground state transition relative to the 1.74→0.72 Mev transition.

[20] F. Ajzenberg and T. Lauritsen, Revs. Modern Phys. **27**, 104 (1955).

TABLE V. Energies of γ rays from a 96% B^{10} target and from a natural boron target.

Observed energy (Mev)	γ-ray energy if full Doppler shift applies (Mev)	Energy difference of levels involved in transition[a,b]	Assignment	Type of radiation
1.023±0.005	1.018	1.022±0.007	B^{10} 1.74→0.72	$M1$
1.438±0.005	1.430	1.435±0.007	B^{10} 2.15→0.72	$M1$
2.134±0.005	2.122	2.138±0.014	B^{11} 2.14→0	$M1$
2.88 ±0.01	2.86	2.866±0.007	B^{10} 3.58→0.72	$M1$

[a] See reference 21.
[b] See reference 23.

At a proton energy of 4.5 Mev it is possible to excite the 3.58-Mev level. The γ-ray peak at 2.88 Mev shown on the top curve of Fig. 7 corresponds to the 3.58→0.72 Mev cascade. At higher energies a weak Compton peak from the 3.58-Mev γ ray was observed but is not shown in Fig. 7.

The energies of the γ rays obtained from B^{10} and B^{11} are listed in Table V. It can be seen that the agreement of the energy values of the two lower energy γ's from B^{10} with the energy differences of the levels involved (as measured by Bockleman *et al.*[21]) is better when no Doppler correction is applied. The calculated transition probabilities for these γ rays (computed on the basis of the single-particle model) indicate lifetimes no less than an order of magnitude shorter than the slowing-down time for the B^{10} nuclei, so that it is not clear whether a Doppler shift occurs. A comparison of the experimental energy of the 2.88-Mev γ radiation with the known difference in the energy levels in B^{10} indicates a Doppler shift, which is also expected on the basis of the calculated transition probability. For the case of the 2.12-Mev γ ray from B^{11} the Doppler shift has been measured[22] and hence there is little doubt but that it should be applied, despite the better agreement of the energy of the uncorrected γ radiation with the excitation energy of B^{11}.[23]

[21] Bockleman, Browne, Buechner, and Sperduto, Phys. Rev. **92**, 665 (1953).
[22] D. H. Wilkinson, Phys. Rev. **105**, 666 (1957).
[23] Van Patter, Beuchner, and Sperduto, Phys. Rev. **82**, 248 (1951).