cerned, increasing monotonically with increasing neutron number, while the excitation energies of the 2^+ states decrease. According to the simplest "strong coupling" approximation in the unified description of the nucleus,[15,16] which identifies the 2^+ state with the first rotational state of a deformed nucleus, this is just as expected: in both Pd and Cd we are moving away from the closed shell at $N=50$ toward greater deformation, i.e., larger values of the intrinsic quadrupole moment Q_0. The nuclei of $_{48}$Cd are presumably somewhat less deformed than those of $_{46}$Pd because their proton number lies closer to the shell at $Z=50$. Now the *position* of the 2^+ state is *inversely* proportional to $Q_0^2(E_{2^+}=6\hbar^2/2\mathcal{J};\ \mathcal{J}\sim Q_0^2)$, while the (upward) *transition probability* to the 2^+ state is proportional to $Q_0^2[B(E2)=5/16\pi(e^2Q_0^2)]$.[15,16] The values of Q_0 obtained from the transition probabilities are listed in the last column of Table I. The values are quite comparable to those we found previously for the odd-Z nuclei $_{45}\mathrm{Rh}^{103}$, $_{47}\mathrm{Ag}^{107}$, and $_{47}\mathrm{Ag}^{109}$,[7] as well as to the spectroscopically measured Q_0 in $_{49}\mathrm{In}^{115}$. It is just such continuity of nuclear properties which seems to support the unified model. The values of Q_0 as derived from the moments of inertia (level positions) follow the same trend but turn out to be about three times larger, a tendency which has been previously noted.[15,17] All transition probabilities are about twenty times greater than would be predicted on the basis of a single-particle transition.

Since all these nuclei have spins of either 0 or $\frac{1}{2}$ (except Pd^{105}), their intrinsic quadrupole moments are not accessible to conventional measurement. The equivalent lifetimes for the transitions we observe here range between 2 and 7×10^{-11} second.

We have obtained additional results in even-even nuclei of Ti, Fe, Zn, Ge, Se, Ru, and Mo, to be published at a later date.

ACKNOWLEDGMENTS

We are very grateful to G. Scharff-Goldhaber, P. Colsmann, and M. McKeown for generously arranging the loan of the enriched isotopes which made this work possible.

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Gamma Rays from the Low-Energy Proton Bombardment of Beryllium†

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The gamma radiation produced in the $\mathrm{Be}^9(p,\gamma)\mathrm{B}^{10}$ reaction at proton energies of approximately 300 kev was investigated with scintillation spectrometers. A three-crystal scintillation spectrometer detected 6.7 ± 0.15, 6.0 ± 0.1, 5.1 ± 0.1, and 4.7 ± 0.15-Mev gamma rays with relative intensities (±25 percent) of 0.15, 0.40, 1.00 and 0.45, respectively. A thick target yield of $(1.2\pm0.3)\times10^{-10}$ gamma per proton at 315-kev proton energy was measured for gamma radiation of 5.1-Mev energy. These gamma rays are produced in transitions to the ground-state and low-lying levels in B^{10} and their relative intensities and yield imply spin 1^- for the level at 6.89 Mev. A limited single-crystal spectrometer detected 0.41 ± 0.02, 0.72 ± 0.02, 1.03 ± 0.03, and 1.43 ± 0.03-Mev gamma rays corresponding to transitions between the low-lying levels in B^{10}. The angular correlation of the 0.72- and 1.03-Mev gamma rays was found to be consistent with a spin of 1^+ or 2^+ for the first excited state of B^{10}.

INTRODUCTION

THE energy levels of the B^{10} nucleus have been studied in a number of nuclear reactions. The results are summarized in the review article by Ajzenberg and Lauritsen.[1] Briefly, low-lying levels at 0.72, 1.74, 2.15, and 3.58 Mev are very well established, having been deduced from inelastic scattering experiments with protons and deuterons (with the exception of the 1.74-Mev state in the case of deuterons). Also, the first level has been seen in the reaction $\mathrm{C}^{12}(d,\alpha)\mathrm{B}^{10}$; the first and second, in the beta decay of C^{10}; the first, second, and third, in the reaction $\mathrm{Li}^7(\alpha,n)\mathrm{B}^{10}$. A level at 4.78 Mev has appeared in the inelastic proton scattering work. The above-mentioned levels and levels at 5.11, 5.17, 5.37, 5.58, 5.72, 5.93, 6.12, 6.38, 6.58, and 6.77 Mev appear in work on the neutron groups from $\mathrm{Be}^9(d,n)\mathrm{B}^{10}$. Further levels resulting from proton capture resonances in Be^9 show up at 6.89, 7.03, 7.19, 7.48, and 7.56 Mev.

The ground-state spin of B^{10} is known[2] to be 3 and the parity even.[3] Sherr and Gerhart[4] present various arguments to show that the first, second, third, and fourth excited states have spins and parities of 1^+, 0^+,

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† Supported in part by the U. S. Atomic Energy Commission.

[1] F. Ajzenberg and T. Lauritsen, Revs. Modern Phys. **24**, 321 (1952). See also forthcoming supplement in the Reviews of Modern Physics. We wish to thank Professor Lauritsen for a preprint of the supplement.

[2] Gordy, Ring, and Burg, Phys. Rev. **78**, 512 (1950).

[3] F. Ajzenberg, Phys. Rev. **88**, 298 (1952).

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1^+, and 2^+, respectively. The parity assignments come from the work of Ajzenberg[3] on the reaction $Be^9(d,n)B^{10}$. The spin assignments are made on the basis of a comparison of the theoretical and observed intensities of gamma ray transitions between the low-lying levels of B^{10} formed in the reaction $Be^9(d,n)B^{10}$ and in the beta decay of C^{10}. Spin-0 assignment for the second excited state is strengthened by the fact that this state does not appear in the inelastic deuteron scattering making it the spin-0 analog of the ground states of Be^{10} and C^{10}. Arguments for the spin and isotopic spin of the levels at 5.11 and 5.17 Mev have also been made.[5]

We have studied the gamma-ray decay of the 6.89-Mev level in B^{10}. Various high-energy gamma rays have been resolved and their relative intensities measured. From the nature of the decay and the yield, the spin and parity of this level may be deduced. Low-energy gamma rays presumably following these high-energy gamma rays have also been studied.

HIGH-ENERGY GAMMA RAYS

Gamma rays of a few Mev in energy can be measured quite accurately with sodium iodide crystal detectors, but for higher energies a single gamma ray gives rise to several peaks in the photomultiplier pulse-height distribution or the peak is excessively broadened. Since the gamma rays resulting from proton capture by beryllium are as high as 6 Mev in energy, we used a three-crystal spectrometer. This has been described previously.[6] Briefly, it consisted of three NaI crystals in a row, the center crystal being 2 in. long by 1½ in. in diameter and the two side crystals being 1 in. long by 1½ in. in diameter. The pulses from the center detector were analyzed by a 10-channel pulse-height analyzer when a triple coincidence between the three detectors occurred. By this means, pulses from the center detector are measured when a pair has been produced in the center crystal and both annihilation quanta escape.

The physical layout and electronic circuitry used were the same as previously reported.[6] The improvement in resolution with the 6.13-Mev gamma ray from $F^{19}(p,\alpha\gamma)O^{16}$ is shown in Fig. 3 of this previous report. A single peak of 7 percent width at half-maximum and a peak-to-valley ratio of 13 to 1 are obtained. The resolution is not as good at lower energies, being 9 percent with the 4.43-Mev gamma ray from $B^{11}(p,\gamma)C^{12}$. It is also poorer at higher energies, being 11 percent with the 11.67-Mev gamma ray from this same reaction. The reasons for this have been discussed previously.

The spectrometer was calibrated with the 6.13-Mev and 4.43-Mev gamma rays mentioned above. In addition, the requirement of triple coincidence was relaxed and three points on the calibration curve resulting from the 2.62-Mev gamma ray from ThC″ were obtained. The calibration curve was linear within the accuracy of the measurement which was two percent at 6 Mev.

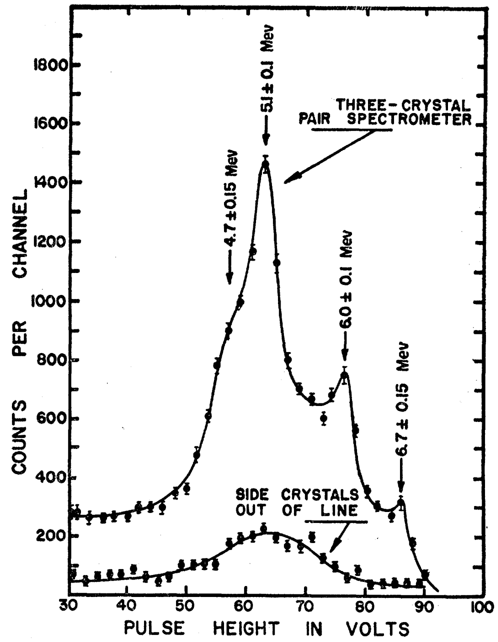

FIG. 1. Spectrum of high-energy capture gamma rays from a thick beryllium target bombarded with 315-kev protons, measured with a three-crystal pair spectrometer.

Gamma rays from proton capture in beryllium were obtained by bombarding a 2 mm thick metallic beryllium target with 100 microamperes of 315±5 kev protons from the State University of Iowa Cockcroft-Walton accelerator. The beam was analyzed and its energy determined by a 90° deflection magnet. The magnet was calibrated using the $B^{11}(p,\gamma)C^{12}$ resonance at 163 kev and the $F^{19}(p,\alpha\gamma)O^{16}$ resonance at 340 kev bombarding energy.

A spectrum of high-energy gamma rays obtained with the three-crystal spectrometer is shown in Fig. 1. The stability of the entire system was checked repeatedly throughout the six hours required to obtain the above spectrum. This was done by increasing the signal level four-fold by an input attenuator preceding the amplifier and measuring the photopeak of the Cs^{137} (663-kev) gamma ray. Shifts were less than 2 percent during any of the runs. Pulse heights during any run were normalized to a standard value by means of the stability checks with the Cs^{137} source.

In Fig. 1, four gamma rays may be seen: 6.7±0.15, 6.0±0.1, 5.1±0.1, and 4.7±0.15 Mev. The last is not completely resolved from the 5.1-Mev gamma ray but its existence is definitely established by the shape of the spectrum. A single gamma ray, such as the 6.13-Mev gamma ray from $F^{19}(p,\alpha\gamma)O^{16}$, produces a single symmetrical peak with a low valley on the low-energy side. On this basis, one must ascribe the asymmetry observed to a 4.7±0.15-Mev gamma ray.

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[5] G. A. Jones and D. H. Wilkinson, Phys. Rev. **90**, 722 (1953).

[6] Carlson, Geer, and Nelson, Phys. Rev. **94**, 1311 (1954).

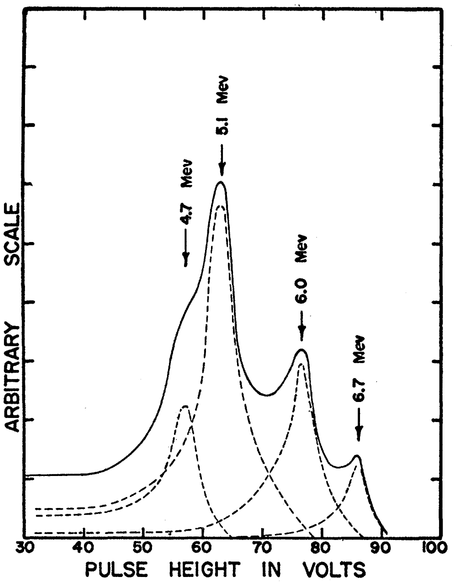

FIG. 2. Analysis of the spectrum of Fig. 1 into constituent gamma rays.

From the known shape of a peak due to a single gamma ray and from the known variation in this shape for different gamma-ray energies, the spectrum was decomposed into its constituent parts. Before this can be done, one must subtract the contribution of true triple coincidences resulting from the detection of other than annihilation quanta in the side detectors. To measure this, the side detectors were moved out of line with the center detector but kept the same distance from the target so that their counting rate was unchanged. The result is shown in Fig. 1, where it was assumed that the angular correlation of any cascades is isotropic. Accidental triple coincidences were measured by delaying the pulses from one side detector and were found to be negligible. If one now takes the difference of the two curves in Fig. 1 and analyzes it into peaks coming from the four gamma rays listed previously, one obtains the curves shown in Fig. 2. Taking into account the change in the pair-production cross section and the resolution, these peak heights give an estimate of the relative intensity of these gamma rays. With an error of ±25 percent the result is 0.15, 0.40, 1.00, and 0.45 for the 6.7-, 6.0-, 5.1-, and 4.7-Mev gamma rays, respectively.

The spectrum of high-energy gamma rays was also studied at bombarding energies of 280±5 kev and 365±5 kev. The aforementioned four gamma rays were found with the same relative intensities within 25 percent as at a bombarding energy of 315 kev. The intensity at the lower energy was 0.55±0.05 that at 315 kev; at the higher energy it was 2.2±0.2 that at 315 kev. Two other thick targets with beryllium from different sources were also used and gave the same results at a bombarding energy of 315±5 kev.

The absolute yield of 5.1-Mev gamma rays was obtained by comparing the counting rate in the peak due to this gamma ray with that in the peak due to the 6.13-Mev gamma ray from the 340 kev proton bombardment of a thick calcium fluoride target. The yield of the latter is known to be 1.74×10^{-8} gamma per proton.[7] The only changes were in the target and bombarding voltage. The peak counting rate due to the 5.1-Mev gamma ray must be obtained from the spectrum in the same manner as in the determination of relative intensities. Corrections for a slight change in resolution and pair production cross section must then be applied to the ratio of the observed counting rates to reduce it to a ratio of intensities. The result is 1.2×10^{-10} gamma of energy 5.1 Mev per proton at 315-kev bombardment of thick beryllium with an error of ±25 percent.

Single-crystal pulse-height distributions from the high-energy gamma rays were measured at 0° and 90° to the beam direction by using the center detector of the three-crystal spectrometer. The target consisted of a piece of 2-mm thick beryllium metal mounted at 45° to the beam direction in the center of a pillbox shaped chamber. The detector viewed the back of the target at either angle from a distance of 3 in. The results are shown in Fig. 3. The peaks result from the superposition of the two peaks from each of the 4.7-, 5.1- and 6.0-Mev gamma rays. Such pulse-height distributions were ob-

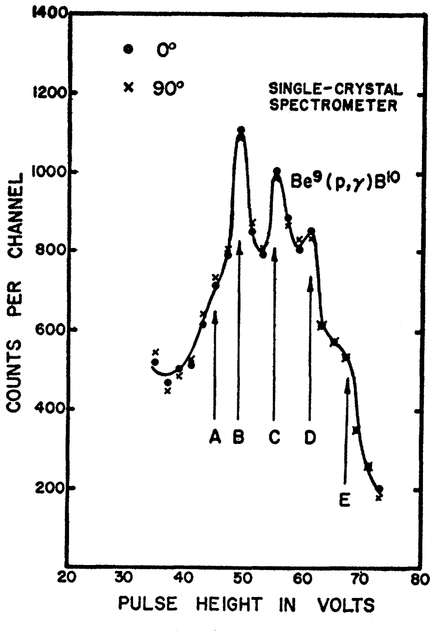

FIG. 3. Spectrum of high-energy gamma rays from a thick beryllium target bombarded with 315-kev protons measured with a single-crystal spectrometer at 0° and 90° to the beam direction. The irregularity at *A* is caused by gamma rays of 4.7 Mev; at *B*, 4.7 and 5.1 Mev; at *C*, 5.1 Mev; at *D*, 6.0 Mev; at *E*, 6.0 and 6.7 Mev.

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[7] Chao, Tollestrup, Fowler, and Lauritsen, Phys. Rev. **79**, 108 (1950).

served for the single 6.13-Mev gamma ray from the $F^{19}(p,\alpha\gamma)O^{16}$ reaction. With the poor resolution of a single-crystal spectrometer, the 6.7-Mev ground-state transition was not observed. Pulses caused by 4.7-Mev gamma rays which lose 3.7 Mev in the crystal appear at *A*. The peaks at *B* and *C* are caused by 5.1-Mev gamma rays which lose 4.1 and 4.6 Mev in the crystal, respectively, with some contribution to the peak at *B* coming from 4.7-Mev gamma rays which lose 4.2 Mev in the crystal. The peaks at *D* and *E* are caused by 6.0-Mev gamma rays which lose 5.0 and 5.5 Mev in the crystal, respectively. Some contributions to the peak at *E* may come from 6.7-Mev gamma rays which lose 5.7 Mev in the crystal. From the *C* and *D* peaks one can say that there is less than 15 percent anisotropy of the 6.0-Mev gamma ray relative to the 5.1-Mev gamma ray. Jacobs, Malmberg, and Wahl[8] used Geiger counters to measure the angular distribution of the total gamma radiation from a thick target bombarded with 340-kev protons and found the radiation to be isotropic within 10 percent.

LOW-ENERGY GAMMA RAYS

The spectrum of low-energy gamma rays was studied with a limited single crystal spectrometer of the same type previously described.[6] Briefly, this consisted of a sodium iodide crystal detector with a 2 in. long by 1½-in. diameter crystal followed by a RCA 5819 photomultiplier and a pulse limiter set to limit all pulses corresponding to gamma-ray energies greater than 2 Mev to the same height. This enables one to expand the gain of the amplifier following the limiter without danger of overloading. The amplifier output was then analyzed by a 10-channel pulse-height analyzer.

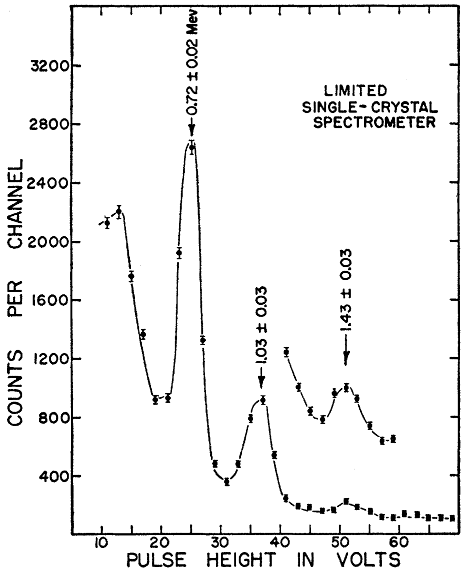

FIG. 4. Spectrum of low-energy capture gamma rays from a thick beryllium target bombarded with 315-kev protons, measured with a single-crystal spectrometer limited at 2 Mev.

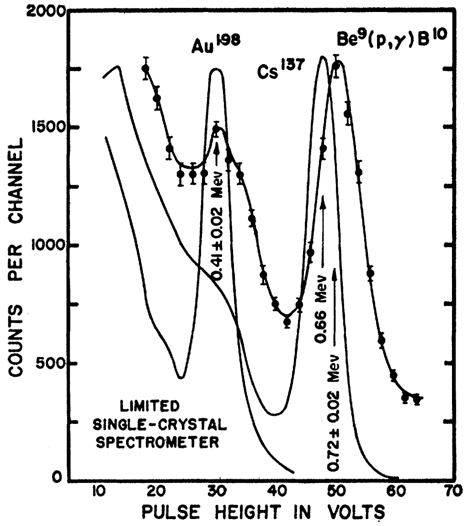

FIG. 5. Spectrum of low-energy capture gamma rays from a thick beryllium target bombarded with 315-kev protons, measured with a single-crystal spectrometer limited at 1 Mev.

The spectrometer was calibrated by using the 663-kev gamma ray from Cs^{137}, the 1.17-Mev and 1.33-Mev gamma rays from Co^{60}, and the 1.60-Mev energy loss from the 2.62-Mev gamma ray of ThC″. Over the range of pulse heights of interest the calibration was linear to within the accuracy of measurement which was 1 percent at 1.6 Mev. The spectrum obtained at a bombarding energy of 315 kev is shown in Fig. 4. Three gamma rays are observed: 0.72±0.02, 1.03 ±0.03, and 1.43±0.03 Mev. The observed peak heights above background of the 1.03- and 1.43-Mev gamma rays relative to that of the 0.72-Mev gamma ray are 0.27±0.03 and 0.05±0.01, respectively. Any peak due to the total absorption of a 1.74-Mev gamma ray in the crystal is less than 0.01 the height of that due to the total absorption of the 0.72-Mev gamma ray. The spectrum was taken at bombarding energies of 255, 385, 440, and 495 kev as well as 315 kev. No change in the relative intensities of the gamma rays was observed.

The limiting was changed to take place at 1 Mev and the spectrometer calibrated by using the 0.41-Mev gamma ray from Au^{198}, the annihilation radiation from Na^{22}, and the 0.66-Mev gamma ray from Cs^{137}. Gamma radiation of energy 0.41±0.02 Mev from the proton bombardment of beryllium at 315 kev was found with an intensity of a few percent of the 0.72-Mev radiation. A more accurate estimate is difficult because the peak is superimposed on the Compton distribution of the 0.72-Mev gamma ray. The peak is definitely caused by a 0.41-Mev gamma ray and not the Compton distribution of the 0.72-Mev gamma ray, for the 0.66-Mev gamma ray from Cs^{137} was found to have no such peak in its Compton distribution. The results are shown in Fig. 5.

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[8] Jacobs, Malmberg, and Wahl, Phys. Rev. **73**, 1130 (1948).

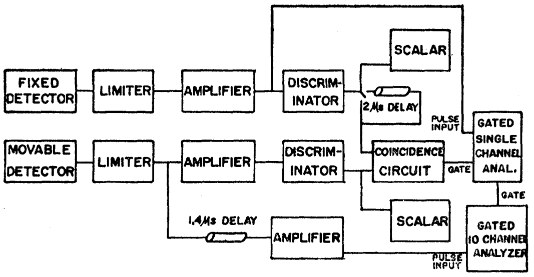

FIG. 6. Block diagram of the electronic circuits for the measurement of the angular correlation of the 1.03- and 0.72-Mev gamma rays.

ANGULAR CORRELATION OF LOW-ENERGY GAMMA RAYS

The angular correlation of the 1.03- and 0.72-Mev gamma rays was investigated with the same thick target and chamber used for the angular distribution measurements. A calcium fluoride target could be substituted for the beryllium target and the known[1] isotropy of the 6.13-Mev gamma radiation used to check the centering of the beam. Two NaI crystal detectors, limited at 2 Mev, were used. A 1-in. long by $1\frac{1}{2}$-in. diameter crystal was used on a fixed detector which viewed the front of the target from a distance of 3 in. at 90° to the beam direction. A 2-in. long by $1\frac{1}{2}$ in.-diameter crystal was used on a movable detector which viewed the back of the target from a distance of $2\frac{1}{2}$ in. at either 0° or 90° to the beam direction. Beam currents of 20 microamperes were used. The bombarding energy was 315 kev.

A block diagram of the circuit is shown in Fig. 6. Pulses from the limiter were amplified by Atomic Instrument Company Model 204B amplifiers (which include the discriminators shown) and coincidences detected by an Atomic Instrument Company Model 502, 0.5-microsecond resolving time, coincidence circuit. A 2-microsecond delay could be interposed in the fixed detector channel to check for accidental coincidences, which were negligible. An Atomic Instrument Company Model 502 anticoincidence circuit was used as a gated single-channel pulse-height analyzer to select pulses from the fixed detector corresponding to the 0.72-Mev gamma ray total absorption peak. Pulses from the movable detector were amplified after a 1.4-microsecond delay and analyzed by a 10-channel pulse-height analyzer. This was gated by the time coincidence of a pulse in the movable detector channel and a pulse in the fixed detector channel having a height corresponding to the total absorption peak of the 0.72-Mev gamma ray. The 10-channel analyzer was set on the pulse heights corresponding to the total absorption peak of the 1.03-Mev gamma ray. All gains and discriminator settings were checked throughout the run and no appreciable shifts were found.

About a thousand coincidence counts were accumulated with the movable detector at 0° to the beam and also at 90° to the beam. The counts were accumulated alternately in many short runs over a period of twenty hours. The coincidence spectrum shows a peak of the same shape as that of the 1.03-Mev gamma ray in Fig. 4. The anisotropy observed is:

$$[W(180°)/W(90°)]-1=-0.12\pm0.04,$$

where $W(\theta)$ is the coincidence rate with the angle θ between the detectors. This value is in agreement with the value of -0.10 ± 0.05 found by Shafroth and Hanna[9] using the $\mathrm{Be}^9(d,n)\mathrm{B}^{10*}(\gamma,\gamma)\mathrm{B}^{10}$ reaction.

DISCUSSION

The level at 6.89-Mev excitation in B^{10} is quite broad.[10] For this reason, *s*-wave proton capture in Be^9 has been assumed for this level.[1] This is certainly consistent with the observed relative angular isotropy. Two possible spins for the level, 1^- and 2^-, result. The latter is ruled out because ground-state transitions would be more probable than transitions to the excited states. Transitions to the ground state are known[11] to predominate overwhelmingly for the 7.48-Mev level which has spin 2^-. In Fig. 7, the known energy levels of B^{10} have been shown with the observed high-energy gamma rays indicated as transitions to the ground and low-lying excited states. The relative intensities of the high- and low-energy gamma rays are in agreement with the mode of decay indicated. The ground-state transitions may be ascribed to the influence of the 7.48-Mev level. This is possible despite the apparent constancy of the relative intensities of the high-energy gamma rays over an 85-kev range in bombarding energy because of the

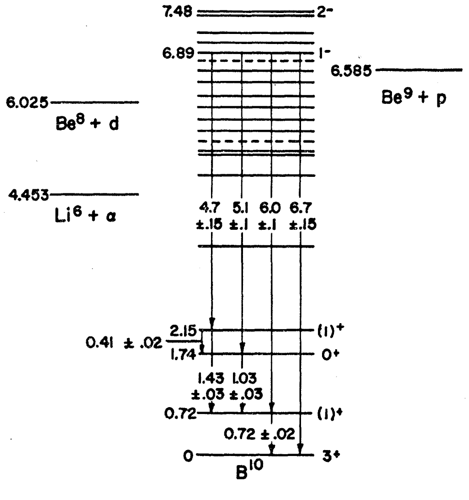

FIG. 7. Energy level diagram of B^{10} and related nuclear configurations with energies on the left in Mev and spins and parities on the right. The excitation in B^{10} is 6.87 ± 0.04 Mev at 315-kev proton bombardment. The transitions indicated are consistent with the measured gamma-ray energies.

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[9] S. M. Shafroth and S. S. Hanna, Phys. Rev. **95**, 86 (1954).
[10] S. E. Hunt, Phys. Rev. **87**, 902 (1952).
[11] W. F. Hornyak and T. Coor, Phys. Rev. **92**, 675 (1953).

175-kev breadth of the resonance and the large dependence of the cross section on penetrability in this energy range.

The yield of the 5.1-Mev gamma rays from a thick target is equal to the integral of σ/ϵ, where σ is the cross section for emission of these gamma rays and ϵ is the energy loss per atom per cm^2 for protons in beryllium. The latter is known[12] over the energy range where there is any appreciable contribution to the integral. The yield is calculated from

$$Y=\sigma_r\int_0^E\left(\frac{\sigma}{\sigma_r}\right)\frac{dE}{\epsilon},$$

where σ_r is the cross section at resonance. Hunt's[10] thin-target yield curve gives the variation of σ/σ_r with energy for the 336-kev resonance. The cross section for emission of 5.1-Mev gamma rays is $(1.2\pm0.4)\times10^{-29}$ cm^2 at resonance. Extrapolating the values given by Hornyak[11] for the 993-kev resonance down to 336 kev, one finds the cross section for emission of gamma rays to the ground state to be about 10 percent of the aforementioned cross section.

Assuming that single-level Breit-Wigner resonance theory is applicable to the 336-kev resonance, the resonance cross section is equal to $4\pi\lambda\!\!\!^{-2}\omega\Gamma_\gamma\Gamma_p/\Gamma^2$, where $2\pi\lambda\!\!\!^{-}$ is the de Broglie wavelength of the proton in the center of mass system, Γ_γ is the partial width for gamma emission, Γ_p is the partial width for proton emission, Γ is the total width of the level, and ω is the statistical weight factor equal in this case to $\frac{3}{8}$. From the measured values[13] of the Be$^9(p,d)$Be^8 and Be$^9(p,\alpha)$Li^6 cross sections, one can estimate the proton width of the level at 6.89 Mev in B^{10} to be either about 20 kev or about 155 kev. Using the expression given by Thomas[14] for the reduced width, one finds the large value to be unacceptable. The partial width for emission of 5.1-Mev gamma rays from the 6.89-Mev level in B^{10} is then 5 ev. This is to be compared with the prediction of the Weisskopf radiation lifetime formula[15] which gives a width of 58 ev for a 5.1-Mev $E1$ transition.

The isotopic spin selection rule calling for a large inhibition of electric dipole transitions between levels with isotopic spin 0 in self-conjugate nuclei[16] is apparently violated in the decay of the 6.89-Mev state to the lower states of B^{10}. The transitions to the 0.72- and 2.15-Mev levels are overwhelmingly $E1$; that to the 1.74-Mev level is $E1$. The state at 6.89 Mev probably has isotopic spin 0 since the nearest levels corresponding to those of Be^{10} are at about 5.2 and 7.6 Mev in B^{10}. The isotopic spin assignment is strengthened by the observation that the Be$^9(p,d)$Be^8 and Be$^9(p,\alpha)$Li^6 reactions both require isotopic spin 0 for the compound state of B^{10}. The 1.74-Mev state in B^{10} has isotopic spin 1 and the 0.72 and 2.15 Mev states in B^{10} have[17] isotopic spin 0. Consequently, one would expect a large inhibition of the transitions to the 0.72- and 2.15-Mev states relative to those to the 1.74-Mev state. Actually, all three are of comparable intensity. A similar case occurs at the 993-kev resonance for which the ground-state transition shows much less inhibition than would be expected on the basis of the isotopic-spin selection rules.[11]

The 1.03-Mev gamma rays and some of the 0.72-Mev gamma rays observed above presumably come from the cascade decay of the 1.74-Mev level in B^{10}. Since this level has spin 0, there is no memory of how it was formed to affect its subsequent decay. The correlation of the cascade radiation reduces, therefore, to a simple double-correlation problem.[18] Effects of the environment of B^{10} on the correlation are expected to be small because, first of all, it is located in a metal[19] and secondly, recent measurements[20] of the lifetime of the first excited state of B^{10} give a value of about 7×10^{-10} second which is rather short for extranuclear influences to have any effect.[19]

The measured anisotropy of -0.12 ± 0.04 is to be compared with that predicted for the various possible spins of the first excited state of B^{10}. The only possible values are 1^+ and 2^+. A spin of 0^+ would rule out the 1.03-Mev transition besides giving isotropy for the correlation and spins higher than 2 would favor a 1.74-Mev transition over a cascade. The spin 1^+ requires the first transition to be $M1$ and the second is predominantly $E2$. The $M3$ and $E4$ components are usually retarded by large factors. Assuming $M1-E2$ decay the predicted anisotropy is -0.10, in agreement with the measured value. The spin 2^+ requires the first transition to be $E2$ but the second may be a mixture of $M1$ and $E2$. The higher multipole components are probably retarded by large factors. The predicted anisotropy is $-(0.10+1.1\delta)$, when δ^2 is the ratio of $E2$ to $M1$ in the mixture and the possibility of higher multipole components is discarded. For any value of δ^2 less than 0.25 percent, this is in agreement with the value found within the accuracy of measurement. Since the radiation lifetime formulas[15] predict a value for δ^2 here of about 0.015 percent, all one can say is that the observed correlation is consistent with either spin 1^+ or spin 2^+ for the first excited state of B^{10}.

We are indebted to Dr. D. H. Wilkinson for a fruitful discussion of this work.

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