TABLE I. Number of δ-rays along C and Be tracks.

Ions	No. of δ-rays per 100 microns at δ-ray max.	Residual range in microns from point of δ-ray max.	No. of δ-rays per 100 microns at 1000 microns from end of track
${}_4Be^9$	32±6	565±60	22±6
${}_6C^{12}$	67±6	225±60	58±6

presumably due to the evaporation of an internal beryllium target which normally is subject to intense high energy proton bombardment.

Ilford C-2 and G-5 plates of various thicknesses were wrapped in black paper and mounted on the end of a probe which made it possible to expose the plates at various radii in the cyclotron. Multiple scattering measurements of the tracks in the emulsion at a cyclotron radius of 40 inches indicated a large intensity of low energy protons. The origin of these protons can be accounted for as being due to the acceleration of $(H_2)^+$ and $(H_3)^+$ at smaller radii. Due to the existing lower frequency limit of the synchrocyclotron oscillator, completely stripped carbon ions were not observed at radii greater than 65 inches and beryllium ions at radii larger than 50 inches.

A study of the δ-rays along the C and Be tracks has been made in electron sensitive G-5 plates. δ-rays of energies greater than about 14 Kev (1.5–2.0 microns) were counted. The results of this study are summarized in Table I. At maximum δ-ray intensity the number of δ-rays as a function of atomic number Z, is expected to be proportional to Z^2. The experimental data as given in Table I are in agreement, within the experimental errors, with this dependence. It is also to be noted that the residual range, from the position of the δ-ray maximum, decreases with increasing Z. The change in the number of δ-rays, per unit length, with residual range was found to be in general agreement with the theoretical calculations.[6]

Multiple scattering measurements of 7 of the carbon nuclei were made by the sagitta method.[7] For a cell length of 250 microns both theory[8] and experiment indicated that the scattering factor[9] is almost independent of energy from 1.1 to 0.1 Bev. The average value of the scattering factor in this energy range was found to be 24.8±1.4, which is in agreement with the theoretical value[8] of 26.4.

An example of a nuclear collision of an artificially accelerated carbon nucleus with a nucleus in the emulsion is shown in Fig. 1, in which 9 particles were emitted. The total energy of the carbon nucleus was about 750 Mev and corresponded to an energy per nucleon of about 60 Mev at the point where the star was formed. Track 1 did not stop in the emulsion and was produced by a heavy fragment which could be lithium. Tracks 2 and 4 were most probably produced by protons of energies of about 50 Mev and 3.8 Mev, respectively. Track 3 which was close to 10,000 microns long was probably produced by an α-particle of energy of about 210 Mev. Track 5 was due to an α-particle of 17 Mev.

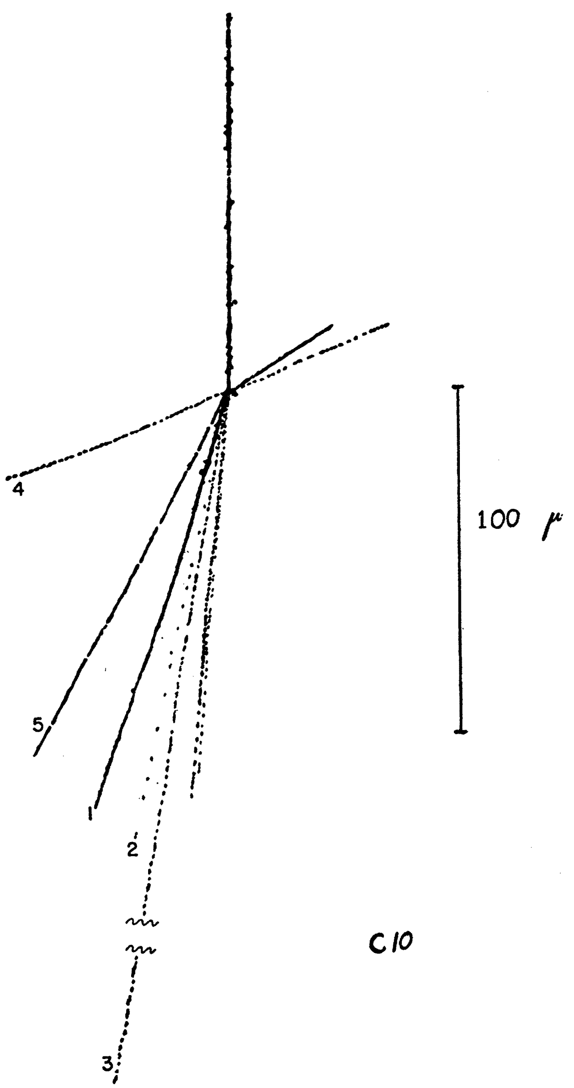

FIG. 1. A projection drawing of a collision of a carbon nucleus in a C-2 emulsion.

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† AEC Postdoctoral Fellow.

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Gamma-Ray Yield from the Proton Bombardment of Boron

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THE gamma-ray yield in the forward direction resulting from the proton bombardment of natural boron has been measured in the energy region between 130 kev and 1 Mev. Gamma-rays were detected with a NaI scintillation counter; the discriminator was set so that the x-ray background from the accelerator was not detected. Proton beams, of from one to two microamperes, from the recently completed University of Kentucky electrostatic generator were focused on the targets. The beam energy was controlled by varying the corona current by use of an error signal from slits placed after the 90° magnetic analyzer. The energy calibration was obtained by measuring the magnet current at the known[1] gamma-ray resonances of fluorine below 1 Mev. By following a definite magnet recycling procedure, repeated runs indicate the energy determinations to be accurate to ±0.25 percent. For the following data, the magnetic analyzer slits were set so as to allow an energy spread of ±0.25 percent.

To investigate the reported[2] possible resonances at 630 kev, 850 kev, and 950 kev, the thick target gamma-ray yield was first determined. A typical result is shown in Fig. 1. No resonance is apparent at 850 kev or 950 kev. By comparing the thick target yield of gamma-rays from boron with that from the proton bombardment of lithium, an upper limit for the yield of these resonances is obtained. This upper limit for the thick target resonant yield is calculated to be 7×10^{-10} gamma-rays per proton.

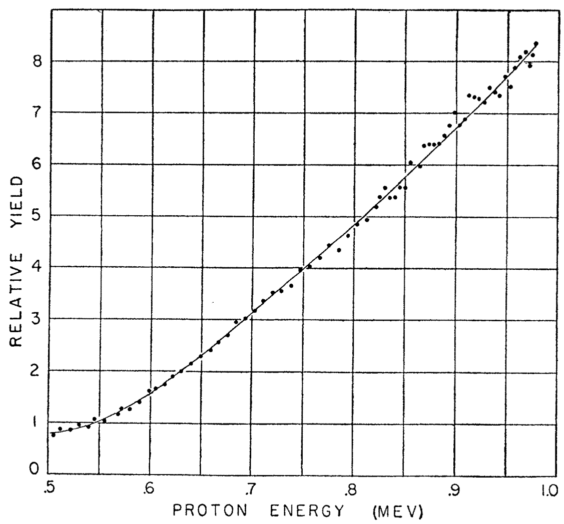

FIG. 1. Thick target gamma-ray yield of boron bombarded with protons.

To investigate the possibility of wide resonances, the thin target yield from boron was obtained. A typical result is shown in Fig. 2. There is no evidence of resonant structure at the higher energies, but there is observed an extremely wide resonance in the vicinity of 600 kev. Tangen[3] has carefully observed the thin target yield of boron to energies as high as 500 kev, and the two sets of data are in good agreement. In order to establish the resonant energy and width of the resonance, the function $Y/[P_0(E)\lambda^2]$ has also been plotted in Fig. 2; Y is the observed yield, $P_0(E)$ the penetrability factor for s-protons incident on the B^{11} nucleus as calculated by Christy and Latter,[4] and λ is the wavelength of the incident proton. After making the penetrability correction, the level width at half maximum appears to be 390 kev. Correcting for target thickness, which is calculated from the measured width at the 163-kev resonance, the resonant energy is calculated to be 670±15 kev.

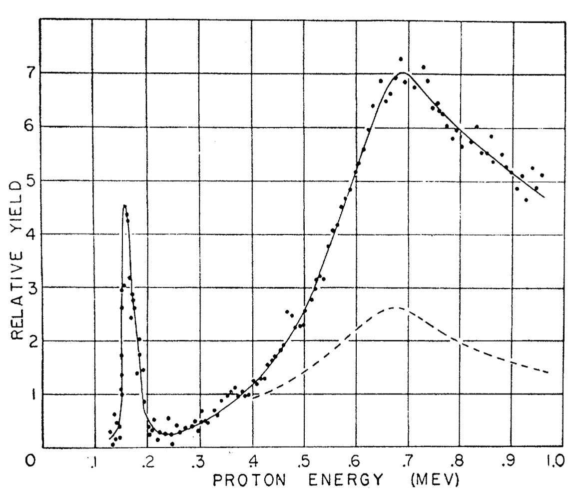

FIG. 2. Thin target gamma-ray yield of boron bombarded with protons. The dotted curve indicates the yield corrected for the penetrability of the incoming proton.

The large width of the observed level would seem to indicate that the observed gamma-rays are from an excited state of Be^8 following alpha-particle emission from the compound nucleus C^{12}. However, Walker[5] has observed the energy spectrum of gamma-rays emitted from the proton bombardment of thick boron targets at 1.2 Mev and did not observe gamma-rays of energies other than those associated with the excited states of C^{12}. A study of the angular distribution of the gamma-rays emitted from this level has been initiated in this laboratory.

While this work was in progress, the existence of a level at proton bombarding energy of 0.67 Mev and width of 0.31 Mev was reported by Huus and Day.[6]

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Spectral Dependence of Thermionic Emission with Activation from (Ba-Sr)O Cathodes over the Visible Region

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As already reported,[1] there seem to be several trapping levels over the visible region in oxide cathodes. Hence, it will be interesting to confirm whether or not the peak intensities of thermionic emission change with activation. In order to investigate this, the following experiments were carried out.

An incandescent lamp of 750 watts was used as a light source and its brightness was kept constant. We used a water filter 1 cm thick to cut off the infrared radiation and an apochromat condenser lens for obtaining intense light. Many glass filters, which successively differ from each other by 10~30 mμ at the short wavelength limit of transmission, were also used to determine the increase in emission due to monochromatic light illumination. A diode having a separated getter chamber was placed in a dark shielding box as the specimen. The cathode of the test tube was illuminated by the light coming through a small opening in the anode. Initially the cathode was in the unactivated state. Considering the space charge, the anode voltage was taken as 20 volts and 50 volts corresponding to an original emission of the order of microamperes and milliamperes, respectively. The temperature of the cathodes was always 800°K. Heat-treatment at 1100°K was performed at the early stage of activation, and then thermionic treatment with an anode voltage of 50 volts at 1000°K was made in order to obtain higher activation.

Figure 1 shows the variation with activation of thermionic emission due to light illumination over the visible region. From this figure it is found that a maximum emission current appears earlier with higher activity. This phenomenon is very similar to the production of C-centers in KCl,[2] except that the dark current falls to a lower steady value after the illumination is removed.

As it was impossible to keep the cathode in the state of constant original emission throughout the observation, the spectral dependence of the increase in emission after illumination for one minute was measured, repeating the measurement as indicated with the arrows in Fig. 2. Typical characteristic curves are shown in this figure. Throughout these observations very small changes of the heating current of the filament were