the activity produced in carbon by a known proton current. The source of protons was the same as described in reference 1, using a $\frac{1}{2}$-in. thick Be target. In a position corresponding about to that marked B in Fig. 1 of this reference was placed a lead box having a 1-in. round hole in one side to admit protons. The protons coming through the hole passed through $\frac{1}{8}$ in. of copper to stop any slow particles, then through the sample to be activated (sheets of 5-mil polystyrene), then were collected in a thick insulated lead block. No defining slits other than the hole were used since other experiments showed that the action of the magnetic field gave ample collimation for this purpose; in fact, an excitation curve taken with a bare stack of carbon plates was reasonably accurate except for some loss of definition near the end of the range. Secondary emission from the collector block is known to be negligible from the fact that very little current is collected by the thin cyclotron targets when traversed by the deuteron beam. The energy of the protons going through the sample was equal to the mean proton energy ($\frac{1}{2}$ deuteron energy $-\frac{3}{4}$ energy loss in traversing Be target $=80$ Mev) less the 18-Mev loss in the $\frac{1}{8}$ in. of copper, or 62 Mev, which is on the flat part of the excitation curve.

The activity measurements were made by comparing the counting rates of the activated polystyrene sheets with a calibrated uranium standard; absorption corrections were small and back-scattering was minimized by mounting the sheets with no backing material. Three sheets were used in each run, and the individual counts agreed excellently. Another sheet behind the collector block served to evaluate the neutron background which gave a 1 percent correction. The proton-induced activity in sheets of 13.9 mg/cm^2 surface density (6.44×10^{20} carbon atoms/cm^2), expressed as the saturation activity at the end of a very long bombardment, was found to be 5950 disintegrations/sec. in the first run and 6010 disintegrations/sec. in the second run.

In order to measure the current, a lead was brought out from the collector to a vacuum-tube electrometer outside the cyclotron shield. This circuit used a Victoreen VX-32 tube as an inverted triode, i.e., the input was connected to the plate, while the grid current was observed. The potential of the cathode was varied manually so as to keep the grid current constant, thus maintaining constant potential differences between the electrodes, and the cathode potential was read. Under ideal circumstances this method would give directly the integrated current during the exposure; in practice, it was found that the cable insulation became very leaky when the cyclotron was running. To minimize this effect, vacuum-insulated cable was used from the center of the cyclotron to a point 12 feet outside the vacuum chamber, the remaining 60 feet of cable being RG-62. A lead shutter in front of the sample box could be closed to make leakage measurements without exposing the sample. With the cyclotron running, it was found that the leakage current varied with collector potential in an ohmic fashion, with an effective resistance of about 2×10^{11} ohms; also, the potential of zero leakage was determined. Then extra capacitance was added, the collector potential was set at 1.5 volts below the point of zero leakage, the shutter was opened, and the cyclotron was run steadily until the collector potential had risen 3 volts. Voltage readings were made at 1-minute intervals during the run. The collected current I is then given by:

$$I=(\Delta V/2R)\ \mathrm{ctnh}(\Delta t/2RC)$$
$$\sim(C\Delta V/\Delta t)[1+(1/12)(\Delta t/RC)^2],$$

where $\Delta V=$ total voltage rise, $\Delta t=$ time of exposure, $R=$ leakage resistance, and $C=$ capacitance. R can be evaluated from the shape of the voltage-time curve; if v represents the deviation of the curve from a straight line at the time mid-point, then:

$$IR=(\Delta V)^2/8v+\tfrac{1}{2}v.$$

In the first run, $\Delta V=3$ volts, $\Delta t=24$ min., $C=9120$ $\mu\mu$fd., and $v=0.25$ volt, from which $R=2.3\times10^{11}$ ohms, $RC=36$ min., and $I=1.97\times10^{-11}$ ampere. In the second run, $R=2.2\times10^{11}$ ohms, and $I=2.09\times10^{-11}$ ampere.

The above activity and current measurements can now be combined to get the activation cross section. Thus we get for the two runs $\sigma_a=0.075\times10^{-24}$ and 0.071×10^{-24} cm^2, respectively. Allowing for possible systematic errors, the result is given as 0.073 ± 0.010 barn.

An estimate of the total proton current is of some interest; from the area and position of the 1-in. hole and the theoretical energy and angle distributions this is estimated to be about 1/40 microampere, which agrees with the theoretical proton yield of 2 percent and the estimated deuteron current of about 1 microampere.

Also of interest is a determination of the relative yields of C^{11} from C, N(Be_3N_2), and O(BeO) samples bombarded simultaneously in a 60-Mev proton beam. The yields per atom were in the ratio C:N:O = 1:0.28:0.36.

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[1] W. W. Chupp and E. M. McMillan, Phys. Rev. **72**, 873 (1947).

The Mean Life of Negative Mesotrons in Sodium Fluoride*

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LAST year Conversi, Pancini, and Piccioni[1] showed that negative mesotrons, stopping in carbon, do disintegrate. This result seemed to indicate that the interaction of mesotrons with nucleons was much smaller than postulated in meson theories.[2,3] Since it seemed essential to prove that disintegration and nuclear capture are actually competitive

processes for every mesotron stopped, and since it appeared probable that the disintegration of negative mesotrons might have some bearing on the lower value of the mean life obtained in aluminum by one of us,[4] we carried out an experiment to determine the mean life of positive and negative mesotrons separately. The absorber chosen was NaF because the results of Sigurgeirsson and Yamakawa[5] indicated that for $Z \approx 10$ the effect should be easily detectable.

The counter arrangement is shown in Fig. 1. Anticoincidences (C_A, C_B, C_C, $-A$) actuated the timing circuit, and time intervals between the firing of counter S and any of the counters D were recorded. The linear sweep used in the timing circuit was automatically calibrated every hour by means of a 1-megacycle crystal oscillator. The iron bars, similar to the ones used by the Rome group,[1] were operated at magnetic saturation (15,000 gauss) and when collecting mesotrons of one polarity rejected all those of the opposite polarity whose energy was smaller than 160 Mev upon leaving the iron. The 16.2 g/cm² of NaF stopped mesotrons with energies smaller than 56 Mev. To check the separation of positive and negative mesotrons the NaF absorber was replaced by an equivalent amount of lead in which no negative mesotrons disintegrate. The effectiveness of the magnetic lens in barring mesotrons of the "wrong" polarity is at least 93 percent. The error in the time measurement

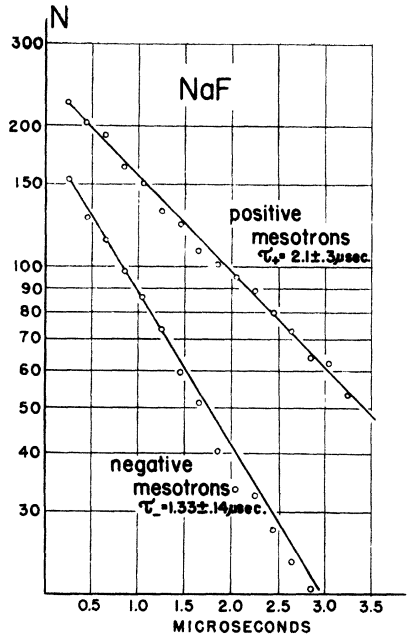

FIG. 2. Results of experiment with NaF.

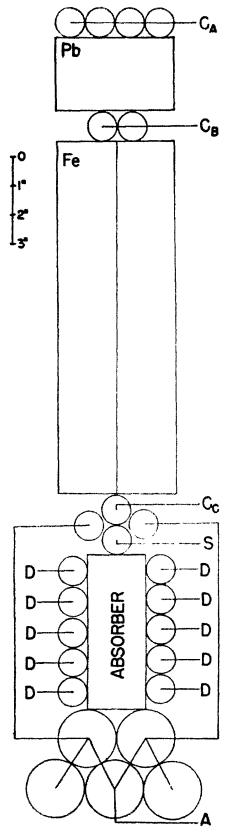

FIG 1. Counter arrangement.

for each individual disintegration, due mainly to the spontaneous lags in the counter tubes, is ± 0.05 μsec.

The results of the experiment with NaF are plotted in Fig. 2. The curve for *negative* mesotrons was plotted *accurately* and yields a mean life of $\tau_- = 1.33 \pm 0.14$ μsec; the curve for positive mesotrons is normalized with the curve for negative ones in such a way that both represent equal numbers of mesotrons stopped in the absorber. The mean life of positive mesotrons obtained from this curve is in agreement with the value of 2.15 μsec obtained by Nereson and Rossi.[6] Considerations published earlier[7] showed that the ratio τ_-/τ_+ may be obtained from the counting rates of disintegrations of positive and negative mesotrons. Using the actual counting rates of this experiment, and an excess of positive mesotrons of 20 percent, one obtains the ratio $\tau_-/\tau_+ = 0.73 \pm 0.10$, which is in satisfactory agreement with the ratio $\tau_-/\tau_+ = 0.62$ derived from the slopes of the disintegration curves of Fig. 2.

Assuming with Wheeler[3] that the probability for capture Λ is equal to kZ^4 (Z = atomic number), one obtains from the here determined mean life of negative mesotrons, $k = 29 \pm 3$. Furthermore, if this Z dependence should be correct, mesotrons, stopping in aluminum, should have a mean life of approximately 0.8 μsec, which would give a satisfactory explanation for the change in the mean life of all positive and negative mesotrons from 2.15 to 1.78 μsec observed in aluminum.[4] Further experiments are now in progress.

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[1] M. Conversi, E. Pancini, and O. Piccioni, Phys. Rev. 71, 209 (1947).
[2] E. Fermi and E. Teller, Phys. Rev. 72, 399 (1947).
[3] John A. Wheeler, Phys. Rev. 71, 320 (1947).
[4] H. K. Ticho, Phys. Rev. 72, 255 (1947).
[5] T. Sigurgeirsson and A. Yamakawa, Phys. Rev. 71, 319 (1947).
[6] N. Nereson and B. Rossi, Phys. Rev. 64, 199 (1943).
[7] H. K. Ticho and Marcel Schein, Phys. Rev. 72, 248 (1947).