reactor was on; no significant field-sensitive effects appeared either in the coincidences or in the single counting rate of the multiplier alone.

Taken together, these observations indicate the existence of coincident events involving on the one hand the appearance of positive particles with low energy and of roughly protonic mass, and on the other hand the discharge of counters by something which could penetrate 0.003 inch of aluminum but failed to penetrate 0.054 inch of aluminum. In addition, the events depended upon the presence of slow neutrons in a manner unconnected with their capture gamma-rays, and they did not involve ionization processes in the residual gas.

The observations would be explained completely and without internal contradiction if neutrons in free flight transform spontaneously into protons with the emission of beta-particles having a maximum energy of less than about 0.9 Mev.

We are not yet in a position to give an accurate value for the half-life of the neutron because of difficulties in evaluating the collecting geometry, in which beta-proton directional correlations are involved. A half-life in the range 10–30 minutes would, however, be consistent with all of our observations.

E. F. Shrader, D. Saxon, and L. C. Miller have collaborated actively in the experiment in the past. We are indebted to W. H. Jordan for generous help in the electronics.

* This document is based on work performed under Contract No. W-7405, eng. 26 for the Atomic Energy Project at Oak Ridge.

[1] J. Chadwick and M. Goldhaber, Proc. Roy. Soc. **A151**, 479 (1935).

Radioactive Decay of the Neutron

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BY using a thin magnetic lens spectrometer in conjunction with an electrostatic field, the positive particle from the radioactive decay of the neutron has been identified as a proton. The source of neutrons was a beam from the Chalk River pile from which the pile gamma-rays had been filtered by a 5-in. bismuth plug at the reacting core end of the collimator. Figure 1 shows a plan view of the apparatus mounted outside of the pile shield with the beam entering the aluminum vacuum tank through a 0.005-in. aluminum window and emerging through a 0.018-in. window into the beam catcher.

The high voltage electrode in the form of a hollow half-cylinder of 0.005-in. aluminum was held at a positive potential to ground

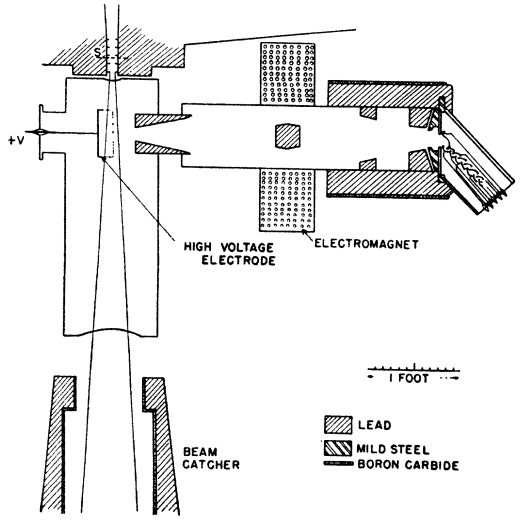

FIG. 1. Plan view of the apparatus.

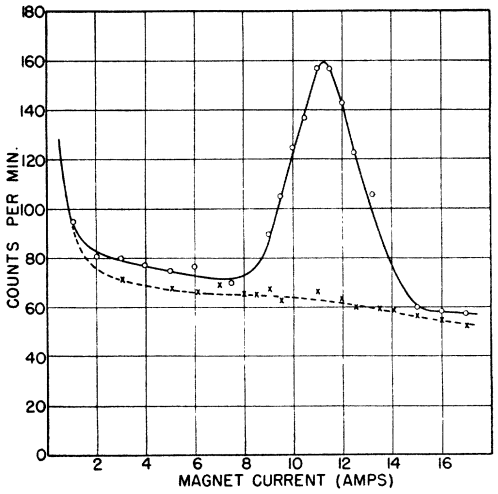

FIG. 2. Electron multiplier counting rate as a function of magnetic field for a potential of 15 kv on the high voltage electrode. The solid curve corresponds to the boron shutter "out" and the dotted curve to the boron shutter "in."

so that low energy positively charged particles such as protons resulting from the neutron decay were deflected through the entrance aperture into the thin magnetic lens spectrometer. The counter at the end of the spectrometer was an electron multiplier shielded from the magnetic field by mild steel shaped to deflect the field away from the beryllium-copper electrodes. A thin shutter of boron carbide power held between two 0.005-in. aluminum windows could be inserted in the beam at S in the pile shield to shut off the thermal neutrons without appreciably scattering the other components of the beam.

The procedure in the experiment was to set a definite voltage on the electrode and record the counting rate of the electron multiplier as the magnet current was varied. Figure 2 shows the results obtained with 15 kv on the electrode, and consists of two curves one with the boron shutter "out" and the other with the shutter "in." The peak on the "out" curve occurs at the correct magnetic field to focus protons of the energy received from the electrostatic field. With the boron shutter "in", the general features of the counting rate curve are similar except that the peak disappears. The difference in the counting rates observed between 2 and 7 amp. and above 15 amp. is probably due to gamma-rays from the capture of thermal neutrons scattered by the vacuum chamber windows and by the air between the vacuum chamber and beam catcher.

At accelerating potentials under 10 kv it would have been possible with the magnetic field available to observe the peak corresponding to singly ionized molecular hydrogen. No significant peaks other than that corresponding to protons were observed at any potential. The pressure in the vacuum tank was varied to see if any of the protons arose from spurious effects in the residual gas. No significant effect was observed with air or oil vapor between pressures of 7×10^{-7} mm and 5×10^{-6} mm of mercury, measured with an ionization gauge. Above the latter pressure the electrostatic field tended to break down under the stray magnetic field near the high voltage electrode. A gamma-ray source placed near the vacuum tank increased the background but did not affect the proton peak. It thus appears probable that the proton peak corresponds to the decay of neutrons, and is not due to other pile radiation or to any effect of the residual gas in the vacuum tank.

An estimate of the half-life of the neutron can be obtained from the number of protons striking the first surface of the electron multiplier, the efficiency of the collecting and focusing system and the density of neutrons in the beam.

To obtain the number of protons striking the first surface of the electron multiplier a set of curves similar to Fig. 2 was obtained at

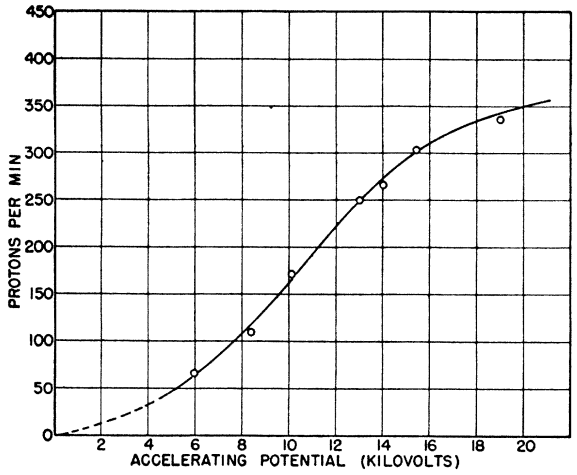

FIG. 3. Variation of number of focused protons with the potential on the high voltage electrode.

different bias settings using a set of discriminators and scalars simultaneously fed from the pulse amplifier. The height of the proton peak was estimated from each curve and a bias curve was then plotted. An extrapolation to zero bias gave an estimate of the number of protons striking the first multiplier electrode on the assumption that at zero bias the multiplier was 100 percent efficient for protons of these energies.[1] Figure 3 shows the variation of the number of protons with the accelerating potential.

A mechanical model[2] was used to investigate the efficiency of the electrostatic collection system at different proton recoil energies and the shape of the high voltage electrode was chosen to minimize the effect of the recoil energy on the resulting efficiency. The acceptance of the magnetic spectrometer was calculated from its geometrical constants. From these estimates the collection and focusing efficiency should reach a saturation value at about 22 kv; it appears from Fig. 3 that the number of detected protons did begin to reach saturation at approximately this potential. The density of slow neutrons in the beam was measured by the activity produced in calibrated manganese foils with and without cadmium. From the values thus obtained the limits for the half-life of the neutron are a minimum of 9 minutes and a maximum of about 25 minutes.

[1] J. M. Robson, Rev. Sci. Inst. **19**, 865 (1948).
[2] V. K. Zworykin and J. A. Rajchman, Proc. I.R.E. **27**, 558 (1939).

The Half-Life of Po^{208} *

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THE properties of Po^{208} have been described in a previous paper[1] in which the half-life was reported as "about 3 years," based on decay during 10 months of a mixture of Po^{208} and Po^{210} (and a small amount of Po^{209} which was not then recognized). By that time the silver plates on which the polonium was deposited had tarnished so badly that two new samples of the same polonium were mounted on platinum for more careful decay measurements. These samples have now been observed for three years. In the mean time Kelley and Segrè[2] have reported the half-life of Po^{208} as 3.0±0.2 years and have described Po^{209}.

Several alpha-counters of the ionization chamber type were used in the course of the measurements. Each time they were used they were standardized by means of a sample of Th^{230}. Cognizance was taken of the growth of daughters in the Th^{230} sample, but this amounts to only 0.05 percent in three years. Statistically significant differences were observed in the counting efficiencies of

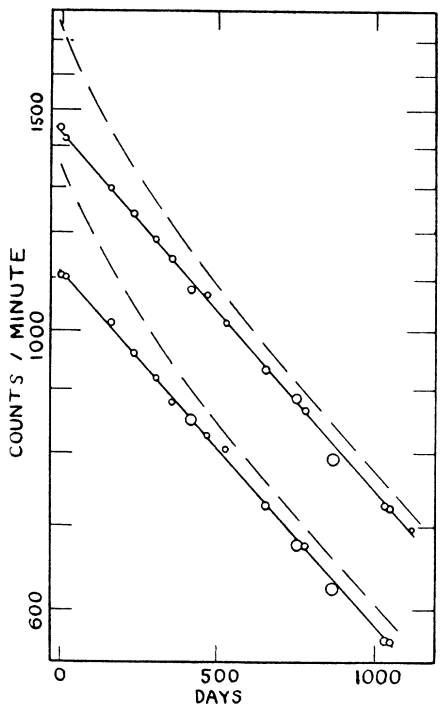

FIG. 1. The dashed curves represent the total activity of each sample; the points and solid lines represent the activity due to Po^{208}. The radius of each circle approximates twice the probable statistical error.

the various counters only on a few occasions when very discordant results revealed external disturbances or defective equipment. The activity due to Po^{210} in each sample was calculated from the pulse-analysis data obtained earlier when the activities due to Po^{208} and Po^{210} were about equal, combined with the value 138.3 days[3] for the half-life of Po^{210}. The contribution of Po^{209} to each sample was derived from pulse analyses made at the end of the experiment, when it amounted to about 4 percent of the activity. Neglect of the decay of Po^{209} during the 3-yr. period causes no significant error if its half-life (estimated as 200 years[2]) is 100 years or more.

The logarithm of the derived counting rate of Po^{208} in each sample is plotted as a function of time in Fig. 1. The best straight lines through these points, derived by the method of least squares with the points weighted inversely as the squares of their probable errors, had slopes corresponding to half-lives of 2.887±0.015 and 2.921±0.015 years.

Pulse analyses taken at the end of the experiment showed broad peaks typical of a moderately thick sample. Since the peaks observed when the samples were fresh were sharp, this was interpreted as evidence that the polonium had diffused somewhat into the platinum. Such diffusion lowers the counting rates because some particles must emerge nearly parallel to the surface of the sample, and must therefore penetrate a large amount of matter, even if the depth is small. A careful consideration of the data led to the conclusion that the average depth of the polonium was about 200A and that the decrease in counting rate due to this cause was of the order of 0.7 percent.

If a correction of 0.03 years is made for the diffusion error, the final result for the half-life of Po^{208} is 2.93±0.03 years. The probable error includes estimates of the reliability of the counting rates and of the corrections for diffusion and for the other polonium activities. It has been assumed that loss of polonium from the sample has not occurred.

* This work was carried out under the auspices of the AEC.
[1] Templeton, Howland, and Perlman, Phys. Rev. **72**, 758 (1947).
[2] E. L. Kelley and E. Segrè, Phys. Rev. **75**, 999 (1949).
[3] W. H. Beamer and W. E. Easton, J. Chem. Phys. **17**, 1298 (1949).