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Beta-Rays from H^3

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The upper limit of the β-ray spectrum of H^3 has been re-determined by a method involving the acceleration of β-particles through a thin window into a Geiger counter. The effective window thickness was determined by acceleration of electrons from a hot filament. The value obtained for the upper limit is 11 ± 2 kev.

I. INTRODUCTION

As a result of the extremely low energies involved, many difficulties have been encountered in studies of the β-rays from H^3. However, numerous attempts have been made to determine the upper limit of the β-ray spectrum. The results of these studies are summarized in Table I. It will be noted that most of the previously published results were obtained by methods involving absorption in gases.

In the present study a somewhat different method was employed. This method involved the use of a counter with a thin window, the minimum thickness of which was determined by accelerating electrons from a hot filament until they were just able to penetrate the window. After the window thickness had been determined, the source of β-rays was mounted on a suitable electrode in vacuum near the window of the counter and accelerating or retarding potentials were applied to the electrode until the β-rays were just able to penetrate the window. From the measured window thickness and the potential necessary to stop the β-rays, the upper limit of the spectrum can be determined.

II. EXPERIMENTAL METHOD

The counter windows consisted of several layers of collodion film. The film was prepared by dropping an amyl-acetate solution of collodion upon a water surface and allowing the solvent to evaporate; the resulting film was removed from the water on a metal frame. Although the thickness of different films varied considerably, the average thickness of the films used was approximately 0.07 mg/cm². In preparing the counter window the films were supported on a brass plate in which holes approximately 1 mm in diameter had been drilled. These holes were confined to a circular area of $\frac{1}{2}''$ diameter on the plate; the drill holes were spaced in such a manner as to give the area transparency of more than 50 percent. When supported in this manner, four layers of film could usually withstand atmospheric pressure. However, eight layers were used in the window employed in the work described below.

In determining window thickness, electrons from a tungsten filament were accelerated toward the brass plate supporting the window and electrons passing through the window were collected by an electrode biased positively with respect to the brass support. It was found to be desirable to have the window mounted between the brass supporting plate and a coarse copper gauze grounded to the plate. Plate and collector currents were read from galvanometers of the appropriate sensitivity.

The high voltage supply consisted of a 10-kv bank of dry cells and a 10-kv electronic supply. These supplies were arranged in such a manner as to give a range of potentials from +20 kv to −20 kv.

In Fig. 1 is given a typical set of data on the thickness of the window. It will be noted that at 12 kv the electrons begin to penetrate the window. As the accelerating potential is increased, more and more electrons pass through. These data were reproduced several times under somewhat different conditions of filament current, and it is believed that the minimum thickness is 12.0 ± 0.5 kv. However, for large plate currents, the results were more erratic than those shown in the figure. The dotted curve in the figure shows the collector current when the brass supporting plate was introduced without a collodion window; this curve was obtained with a low filament

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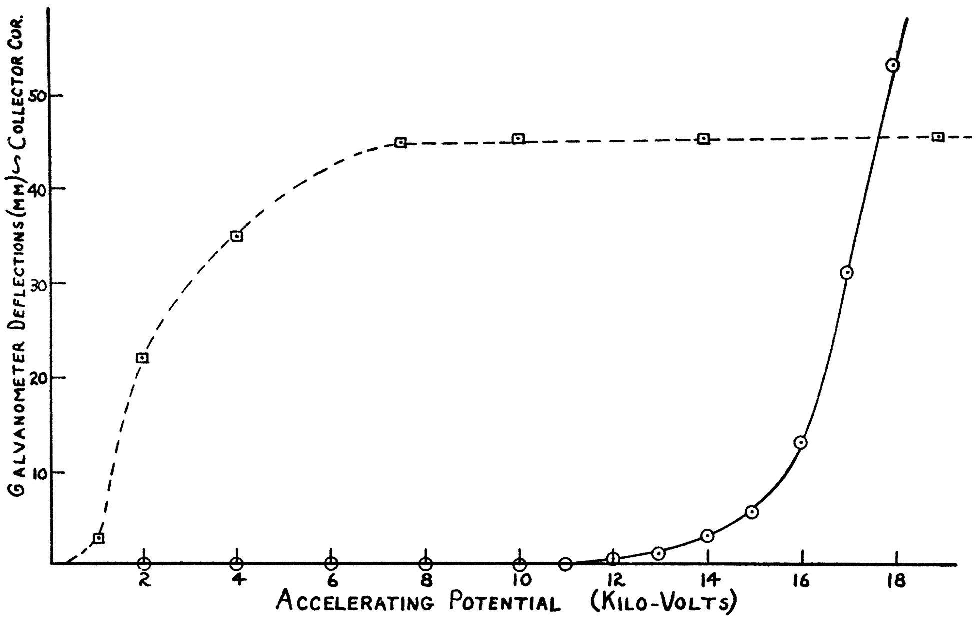

FIG. 1. Collector current as a function of accelerating voltage. Solid curve: Current transmitted by window. Dotted curve: Current transmitted by perforated brass support without window (at lower filament current).

TABLE I. Previous studies of H^3 beta-rays.

Investigators	Method	Upper limit kev	Reference
Libby and Lee	Magnetic	13±5	Phys. Rev. **55**, 245 (1939)
Alvarez and Cornog	Ion pairs per unit volume of gas	18*	Phys. Rev. **57**, 248 (1940)
O'Neal and Goldhaber	Range in argon-alcohol mixture	15±3	Phys. Rev. **58**, 574 (1940) Phys. Rev. **60**, 359 (1941)
Brown	Range in helium	9.5±2	Phys. Rev. **59**, 954 (1941)
Nielsen	Droplets in cloud chamber	14.5±1 (11.7)*	Phys. Rev. **60**, 160 (1941)

* Values obtained on Fermi theory from observed value for mean energy.

current. In both examples shown the plate current was emission limited.

In obtaining the data on the H^3 β-rays, a long counter with a 0.001″ tungsten wire as the high voltage electrode was used. The gas employed was argon at atmospheric pressure. This argon was allowed to flow through a flask containing absolute alcohol. With a sufficiently high voltage, satisfactory performance as a fast Geiger counter was attained. The brass plate supporting the window was mounted in a port in the side wall of the counter. This brass plate with a wax seal also served to seal one end of the glass vacuum system in which the β-ray source was mounted. The pressure in the vacuum system at all times was 10^{-5} mm of mercury or less.

The source was prepared by R. M. Potter and consisted of a thin layer of aluminum oxide hydrated with water containing $H_2{}^3O$. In the preparation of the source, a freshly polished aluminum disk $\frac{3}{4}$″ in diameter was heated to 600°C in an atmosphere of oxygen. After the disk had cooled in vacuum, water vapor containing $H_2{}^3O$ was admitted to the system and was allowed to react with the thin oxide coating of the disk. Sources prepared in this manner proved satisfactory. The water in the hydrated oxide coat showed no appreciable tendency to be removed by subsequent pumping.

The aluminum disk supporting the source served as an electrode to which accelerating and retarding potentials could be applied. The disk was mounted approximately $\frac{1}{2}$″ from the brass plate supporting the window. Previous tests had

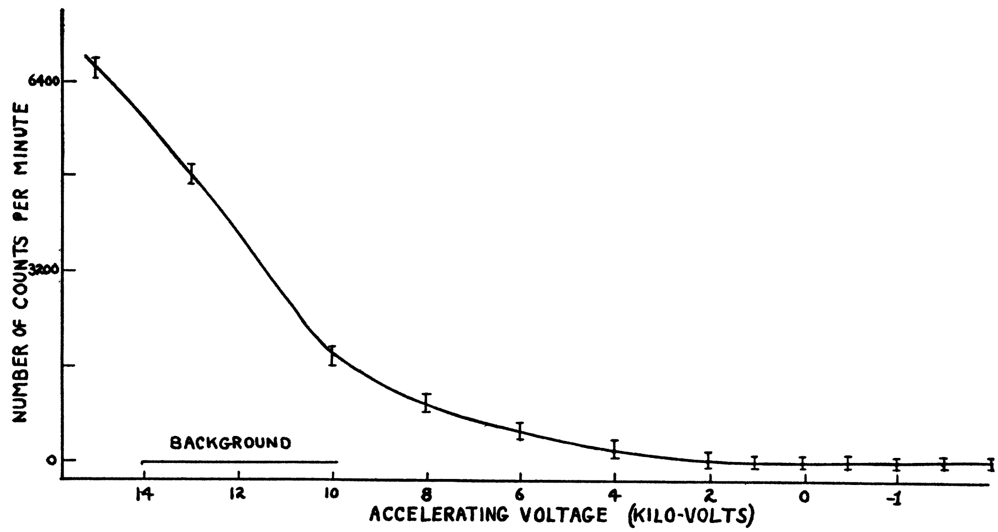

FIG. 2. Counting rate above background as a function of the acceleration voltage. The limits of error shown for the counting rate are three times the probable error. Background: 2133±20 c/min.

revealed no spurious effects in the counter when an uncoated brass disk had been mounted similarly and subjected to accelerating potentials. In obtaining the β-ray data, a scale-of-64 circuit and a mechanical register were employed. Data were taken for three-minute intervals at various accelerating potentials and the background observed for zero accelerating potential was checked for three minutes between each observation interval. The background was remarkably constant throughout the entire period during which measurements were in progress.

The observed counting data are shown in Fig. 2. It will be noted that the counting rate is high for large accelerating potentials and becomes indistinguishable from the background when the accelerating potential is reduced to 1 kv. Further reduction in accelerating potential is without observable effect, although it is possible that the use of a stronger source might have yielded more accurate data on this point. However, it is believed that the observed end point is within ±1.5 kv of the true value.

III. DISCUSSION OF RESULTS

Taking the observed value for minimum window thickness as 12 kv and the accelerating potential necessary for penetration as 1 kv, one is led to a value of 11 kev for the upper limit of the β-ray spectrum of H^3. With the worst possible combination of errors, the limits can be set as 11±2 kev.

This value is somewhat below the value of 15±3 kev obtained by O'Neal and Goldhaber and above the value 9.5±2 kev reported by Brown. However, in both cases the extreme limits of error overlap the values obtained in the present study. The value 14.5±1 kev Nielsen obtained by linear extrapolation is definitely higher than the present results; however, the value for the upper limit obtained on the basis of the Fermi theory from Nielsen's value of 6.5 kev for the mean energy is 11.7 kev, a value in excellent agreement with the present results.

In connection with the results obtained in the present work, one perhaps serious weakness should be noted especially. The results are based on a series of careful measurements with a single counter window, and the writers feel that if sufficient time had been available a more accurate value could have been obtained by measurements involving several different window thicknesses. It is also suggested by the writers that a repetition of the present experiment with an electron multiplier in place of the counter would be desirable, since, in this case, a window would not be used and the upper limit could be obtained directly from the retarding potentials.

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