Beta Spectrum of C^{14}

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(Received October 14, 1954)

A uniform thin source enriched with C^{14} was formed by vacuum evaporation of metallic lithium which was subsequently exposed to water vapor and carbon dioxide. The Kurie plot shows no deviation from linearity above 7 kev. The maximum energy of the beta spectrum was found to be 158.5±0.5 kev.

I. INTRODUCTION

THE beta spectrum of C^{14} has been studied carefully by many investigators,[1–10] and while general agreement exists on the end-point energy a question still remains as to its shape. Past studies by Cook, Langer, and Price,[2] Warshaw,[6] and Angus, Cockcroft, and Curran,[3] along with the recent results of Mize and Zaffarano,[9] all show deviations from a straight line Kurie plot. Zweifel,[11] by calling attention to second-order correction terms, hopes to show that the concave shape observed by Mize is consistent with beta-decay theory. In contradiction to the above results Feldman and Wu,[5] and Wu and Schwarzschild[8] have presented experimental evidence that the Kurie plot is straight to 25 kev.

A great difficulty in C^{14} studies has been the preparation of thin uniform sources. Many of the past investigations[2,4–6,9,10] have been with sources prepared by depositing suspensions or solutions containing C^{14} on films. These methods result in lumps, either as a result of original granules or crystallization in drying. Investigations by Lane[10] showed that carefully prepared sources of average density 0.03–0.05 mg/cm^2 had densities of approximately 1.5 mg/cm^2 in the individual grains. Wu and Schwarzschild[8] were able to obtain a thin (50-μg/cm^2) source by vacuum evaporation of succinic acid onto a Formvar backing.

A method has been developed by the present authors which makes possible the vacuum evaporation of thin uniform sources of 6-μg/cm^2 surface density, containing enriched C^{14}. No protective coatings are necessary. Using thin uniform sources in an intermediate-image type spectrometer,[12] one obtains straight Kurie plots to 7 kev after correcting for the efficiency of the scintillation counter.

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II. PROCEDURE

To obtain uniform thin C^{14} sources, the following procedure was used. Metallic lithium was vacuum-evaporated onto thin collodion films. Lithium was used because its low Z minimized scattering. While still in the vacuum, the films were placed in a small vacuum desiccator. After sealing the desiccator it was removed from the vacuum chamber and radioactive carbon dioxide and water vapor were admitted into it. The water vapor reacted with the metal forming lithium hydroxide and this in turn reacted with the carbon dioxide to form lithium carbonate. At the low pressures used, the complete reaction required a few hours. The low reaction rate prevented film breakage from the heat of reaction. Within experimental error, the completed sources were found to be uniform. Surface densities were measured with a microbalance.

To prevent possible source charging after they were placed in the spectrometer, the sources were immersed in a cloud of electrons every few minutes. The heated filament supplying the electrons was not left on while data were taken, because it increased the background count in the photomultiplier tube.

An estimate was made of the capacity of the sources and from their known activity it was possible to calculate the rate at which the potential of the sources would increase under the extreme condition that no leakage of charge occurred. The periods between turning on the filament were chosen so that even under this extreme condition, charging would be negligible.

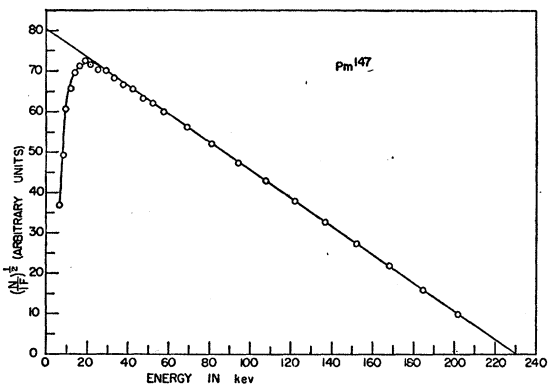

FIG. 1. Kurie plot of Pm^{147}. Surface density of 0.2 μg/cm^2 on a collodion backing of 4 μg/cm^2.

To check the linearity of the spectrometer and to correct for the loss of counts below 25 kev because of counter efficiency, an extremely thin Pm^{147} source was used. Langer, Motz, and Price[13] have shown that Pm^{147} has an allowed shape above 8 kev. The Pm^{147} source was evaporated onto a 4-$\mu g/cm^2$ collodion film in a vacuum. It had a surface density of less than 0.2 $\mu g/cm^2$. A screening correction was made on the Pm^{147} data by interpolation in the table of Reitz.[14] The screening correction for C^{14} was found negligible. All data were corrected for the six percent resolution of the spectrometer.

III. RESULTS

Figure 1, a Kurie plot of Pm^{147}, illustrates the linear characteristic of the spectrometer. This information was used in correcting the C^{14} data at low energies.

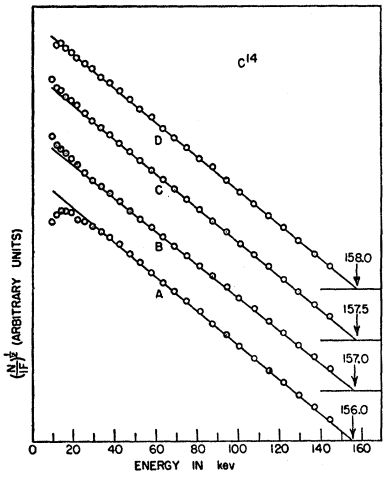

FIG. 2. Kurie plots of C^{14}. The source for curve A, 30–50 $\mu g/cm^2$ $BaCO_3$ on a backing of 4 $\mu g/cm^2$ was deposited from a suspension. The Li_2CO_3 sources for curves B, C, and D were vacuum evaporated on collodion backings 6 ± 2 $\mu g/cm^2$. Surface densities are: B, 40 ± 10 $\mu g/cm^2$; C, 25 ± 6 $\mu g/cm^2$; D, 10^{+5}_{-2} $\mu g/cm^2$.

The effects of variations in source thickness and preparation are shown in Fig. 2. Curve A was obtained by using a source with an average surface density of 30–50 $\mu g/cm^2$ prepared from a suspension by Lane[10] using ultrasonic agitation. Curves B, C, and D illustrate the effect of source thickness when prepared by the vacuum evaporation technique described above. Sources B, C, and D had surface densities of about 40, 25, and 10 $\mu g/cm^2$ respectively. The curves were corrected for

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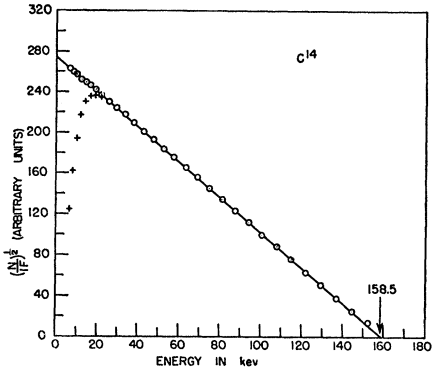

FIG. 3. Kurie plot of C^{14}. Vacuum evaporated source consisting of 6^{+4}_{-2} $\mu g/cm^2$ Li_2CO_3 on a collodion backing of 6 ± 2 $\mu g/cm^2$. Data corrected below 25 kev for detector efficiency. Crosses represent data before correcting for detector efficiency.

detector efficiency below 25 kev. It is interesting to note that although sources A and B had approximately the same average surface densities, their low-energy deviations differ markedly.

Figure 3 presents the results obtained by using a vacuum evaporated source having a surface density of (6^{+4}_{-2}) $\mu g/cm^2$ on a collodion film of (6 ± 2) $\mu g/cm^2$. The Kurie plot shows no deviation above 7 kev, within the probable error. This source gave a maximum counting rate of about 20 000 counts/min. Carbon enriched to about 40 percent C^{14} obtained from C. S. Wu was used in this source.

These data are consistent with the interpretation of an allowed transition for C^{14} according to Gamow-Teller selection rules with $\Delta I=1$, no.[8]

One notes that deviations from linearity as observed in curves B, C, and D of Fig. 2 and Fig. 3 are at the approximate energies predicted by the formula of Hamilton and Gross.[15]

It is observed that the end-point energy increases progressively with decreasing source thickness. A value of 158.5 ± 0.5 kev is obtained with the thinnest source. This is in general agreement with the results of other investigators.

IV. ACKNOWLEDGMENTS

The authors wish to express their gratitude to Dr. C. S. Wu for making available the enriched carbon used in some of the sources and to R. O. Lane, J. H. Talboy, Jr., and E. W. McMurry for suggestions and assistance during the experiment.

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