Beta-Ray Spectrum of K^{40}

DAVID E. ALBURGER
Brookhaven National Laboratory, Upton, Long Island, New York*
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IN a previous communication[1] the results of a spectrometer measurement on K^{40} beta-rays were presented. The source was KCl, 18.5 mg/cm² in thickness, enriched to 1.2 percent K^{40}, giving a maximum yield less than background. The end point occurred at 1.40±0.03 Mev and the apparent shape was that of an allowed type spectrum above 500 kev. Such a shape is in contradiction to the theory of forbidden beta-decay and the predictions of Marshak[2] for K^{40}. Since the known spin change is 4, Marshak showed that with parity change the transition should be third-forbidden and, for either the axial vector or tensor interactions permitted in this case, the factor $c=q^6+7q^4p^2+7q^2p^4+p^6$ [where $q=W_0-W$, $p=(W^2-1)^{\frac{1}{2}}$, W is the energy in units of mc^2, and W_0 is the end-point energy] multiplies the usual Fermi function. The actual spectrum should therefore be distinctly different from the allowed form.

During publication of this earlier result on K^{40} the first of the newly discovered series of first-forbidden type beta-ray emitters, namely Y^{91}, was reported by Langer and Price.[3] Making use of Y^{91} mixed in various amounts of KCl, Feldman and Wu[4] showed that thicknesses of 20 mg/cm² distorted the Y^{91} spectrum into the allowed shape in the upper two-thirds range of energies. They concluded from this that the K^{40} beta-ray spectrum probably did not have the allowed shape. The first clear evidence was given recently by Bell, Weaver, and Cassidy.[5] Using a scintillation spectrometer and 2.5-mg/cm² thick sources of KCl enriched to 1.3 percent K^{40}, they found a forbidden type spectrum agreeing with the factor, c, from 700 kev to the end point at 1.36±0.05 Mev.

Improved techniques of electromagnetic separation have recently enabled C. P. Keim and co-workers at Oak Ridge to increase substantially the K^{40} enrichment factor. The result is that a small quantity of potassium (in KCl) containing 7.13 percent K^{40} has become available.[6] This has made possible conventional spectrometer measurements without excessive distortion due to source thickness. In the present work a source 4 cm² in area was deposited on 0.5-mg/cm² Nylon by precipitating a saturated drop of KCl solution with acetone and rapidly evaporating the remaining liquid by hot air. Examination showed that small crystals were formed although a certain amount of clustering of crystals could not be prevented resulting in noticeable nonuniformities. The average thickness was 2.4 mg/cm².

To study the effects of this type and thickness of deposit, comparison runs were made on P^{32} which is known to have the allowed shape.[7] In the lower curve of Fig. 1 is shown the Kurie plot for a thin source (~0.3 mg/cm² deposited on 0.5-mg/cm² Nylon)

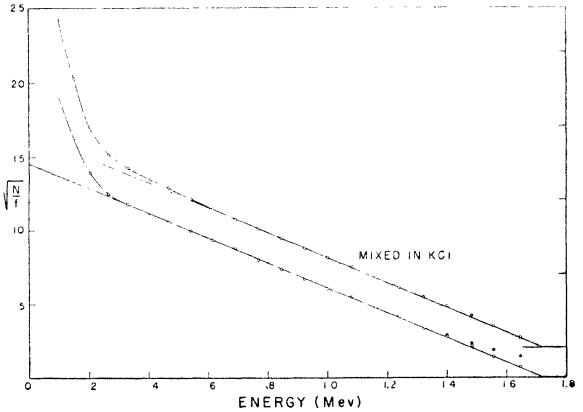

FIG. 1. Kurie plots of P^{32} beta-ray spectrum showing effects of 17 percent resolution and 2.5-mg/cm² source thickness.

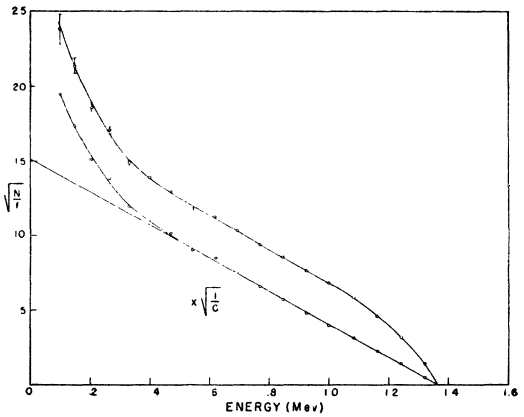

FIG. 2. Kurie plot of K^{40} beta-ray spectrum with and without the theoretical correction factor.

obtained using 17 percent resolution and the same geometry as for K^{40}. Points were corrected for resolution by a graphical integration method similar to previous work[8] on Be^{10}. Only the highest four points are appreciably affected and it is seen that with the corrections included the plot is linear down to about 300 kev. P^{32} was then mixed in ordinary KCl and a 2.5-mg/cm² deposit made by the same procedure used on K^{40}. Deviations are larger and occur up to about 550 kev, as shown in the upper curve of Fig. 1, but the remainder of the curve is linear to the end point. Counter window corrections at low energies have been made in both cases.

The K^{40} source gave at the maximum a yield of 15.8 counts per minute above a background of 18.2 per minute, requiring a total of approximately 170 hours of counting to obtain suitable statistics. The ordinary Kurie plot, including resolution and 2.8-mg/cm² counter window corrections, is shown in the upper curve of Fig. 2. The lower curve includes the correction factor, c, and is linear from about 500 kev to the end point at 1.36±0.03 Mev. Calibration was taken from the P^{32} Kurie plot using an end point of 1.715 Mev, representing the mean of values given by Siegbahn[7] and Agnew.[9] Comparison of this data with the P^{32} thick source result indicates probable agreement of the K^{40} spectrum with the factor, c, to energies well below 500 kev.

To test the uniqueness of the K^{40} spectrum shape the correction factors $\alpha=q^2+p^2$ and $D_2=q^4+10/3q^2p^2+p^4$, generally associated with first- and second-forbidden beta-ray spectra, respectively, were applied to the data. The α-curve shown in Fig. 3 is non-linear, but the D_2 corrected curve appears to be linear above 500 kev

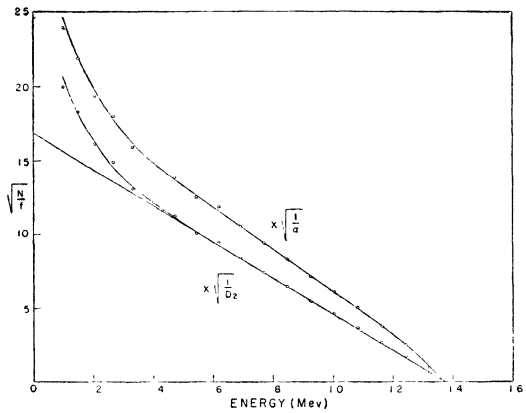

FIG. 3. K^{40} Kurie plot corrected by first-forbidden (α) and second-forbidden (D_2) correction factors.

within the statistical errors. Due to the close similarity of the second- and third-forbidden correction functions it will be difficult to reject the former in the case of K^{40}. The two fourth-forbidden correction factors (spin change 4, no parity change) given by Marshak need not be considered since they are readily distinguished from the second- and third-forbidden factors. For the present the beta-ray spectrum of K^{40} may be regarded as agreeing with the theory although unique proof of this is not possible with the data presented here.

The author is indebted to Dr. C. P. Keim of Oak Ridge for his special efforts in furnishing the enriched source making this experiment possible.

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Evidence from Cosmic-Ray Bursts for a Nuclear Cascade Process*

G. N. WHYTE
Palmer Physical Laboratory, Princeton University, Princeton, New Jersey
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THERE exists considerable indirect evidence for a substantial multiplication of the star-producing component of the cosmic radiation by a nuclear cascade process. For example, Hazen[1] has reported that more than half of the stars observed in a cloud chamber at 10,000 ft. are producted by neutrons; since most, if not all, of such neutrons are believed to *originate* in stars, this observation implies a nuclear cascade. Bernardini *et al.*[2] conclude from photographic plate data on stars that "each primary proton gives rise on the average to more than 10 secondary nucleons having energies of the order of magnitude of some hundreds of Mev." A number of cloud-chamber pictures[3,4] have actually shown an ionizing particle from one star giving rise to another star. The experiments described below provide a somewhat more direct measure of the build-up of the star-producing component in the atmosphere.

A number of thin-walled, spherical ionization chambers have been flown to altitudes exceeding 90,000 ft. at geomagnetic latitudes 0°, 29° and 35°N, extending the work done by Coor[5] at 52°. Each chamber was 30 cm in diameter and was filled with pure argon at 1.4 atmospheres. Electron collection was used. Burst sizes were measured in terms of standard pulses due to polonium alpha-particles, with which the chambers were calibrated periodically. Bursts ranging in size from 0.7 to 20 Po alpha were recorded.

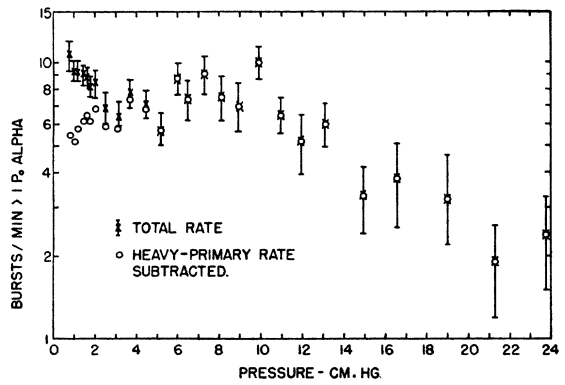

FIG. 1. Variation of burst rate with atmospheric depth.

The flights were sent up by balloon from the U. S. S. Norton Sound in the Pacific during July and August of 1949.

The crosses in Fig. 1 show the variation of the burst rate at 0° as a function of atmospheric depth for bursts greater than 1 Po alpha. The points have been obtained by averaging the results of 3 flights. The initial rapid fall-off in the rate with increasing depth is believed to be due to heavy primary nuclei of $Z \geq 12$, which can cause bursts by ionization in passing through the chamber and which are quickly absorbed by collisions with air nuclei. Bradt and Peters[6] have measured the primary fluxes and mean free paths for collision of such particles at 30° and 51°. From the approximate energy spectrum deduced from these measurements by Vallarta[7] and the geomagnetic cut-off energies at 30° and 0°, one can estimate the flux at 0°. Using this flux and the appropriate mean free paths, one can calculate the burst rate to be expected from heavy primaries as a function of atmospheric depth.

The circles in Fig. 1 have been obtained by subtracting the heavy primary rate from the total rate. Coor has estimated the burst rate due to electron showers at these altitudes to be quite negligible, so that the corrected rate is believed to be due predominantly to nuclear disintegrations and furnishes a measure of the flux of star-producing particles. It will be observed that this flux increases with increasing depth to a maximum around 7 cm Hg before falling off in the usual fashion. Such behavior is consistent with a nuclear cascade picture, according to which each primary particle produces a star, some of the secondaries from which are in turn able to produce stars, the process continuing to the stage where the secondaries have insufficient energies to cause further disintegrations.

A more complete and quantitative report on this work is in preparation.

Sincere thanks are due Dr. G. T. Reynolds for his interest and advice, Mr. Robert Price for his assistance with the flights, and the personnel of the U. S. S. Norton Sound for their unfailing cooperation.

* Assisted by the joint program of the AEC and the ONR.
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Optical Absorption in Strontium Oxide Films

ROBERT L. SPROULL
Department of Physics, Cornell University, Ithaca, New York
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MEASUREMENTS of the optical absorption of strontium oxide were undertaken as part of a study of the properties of the alkaline earth oxides. The technique and apparatus used were identical with those used by Tyler[1] in his study of barium oxide films.

A platinum-rhodium (Baker No. 750 alloy) filament, 0.005 in. $\times$0.092 in., was outgassed in vacuum at 1600°C for two hours. It was then coated to a depth of about 20 mg/cm^2 with Mallinckrodt "ultra-pure" strontium oxide in a minimum of nitrocellulose, amyl acetate binder (tested for the absence of barium). The filament was heated slowly in the vacuum system, the carbonate converted to oxide, and outgassed for four hours at 1350°C. During this period, any barium oxide should evaporate preferentially. This selective evaporation has recently been analyzed by Moore and Allison,[2] whose work indicates that the concentration of barium oxide in a BaO-SrO mixture should be considerably reduced by this procedure. Fused quartz plates were coated by evaporation from the strontium oxide source thus prepared.