# *INTERNAL BREMSSTRAHLUNG ACCOMPANYING THE BETA DECAY OF* $Ca^{45}$

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Submitted to JETP editor July 1, 1962

J. Exptl. Theoret. Phys. (U.S.S.R.) 44, 45-47 (January, 1963)

The internal bremsstrahlung spectrum accompanying the beta decay of $Ca^{45}$ was measured with a single-channel scintillation spectrometer with a NaI(Tl) crystal at energies from 40 to 215 keV. The experimental spectrum was compared with that calculated from the Knipp and Uhlenbeck and from the Bloch theory. It is demonstrated that at low energies the agreement with the theory is good, but at energies above 130 keV the experimental values differ from those computed theoretically and exceed them at an energy of 215 keV by 35 percent.

In the past few years a number of works have been published on the investigation of spectra of the internal bremsstrahlung accompanying the beta decay of nuclei with various atomic numbers and beta end-point energies. However, the number of isotopes on which this phenomenon has been studied is not large, and this is particularly true of the range of small Z and low beta end-point energies, in which only $S^{35}$ is well investigated. The $Ca^{45}$ nucleus whose decay is allowed and whose end-point beta-particle energy is 256 keV is of a similar type. In the literature available to us we found no reference to the study of the internal bremsstrahlung of this nucleus.

In order to exclude instrument errors, we employed two types of electronic devices and various photomultipliers. At first, we used a scintillation spectrometer with a FÉU-19 photomultiplier built in our laboratory; subsequent measurements were carried out on a standard AADO-1 pulse-height analyzer and with a FÉU-11 photomultiplier. In both cases we used a NaI(Tl) crystal with a diameter of 29 and a thickness of 14 mm packed in an aluminum container. The stability of the spectrometers was tested during an extended period of time at various loads. After switching on, the apparatus was heated for no less than 3 hours before measurements were taken. The temperature in the laboratory was kept approximately constant.

The $Ca^{45}$ sources were prepared from a calcium chloride solution and powdered $CaCO_3$ spread in a thin layer on a 0.1-mg/cm$^2$ thick organic film. Owing to the hygroscopic nature of the samples, they had to be covered over by a similar film. The mounting of the film with the source and the relative position of the source, the holders and the ring supporting the source, and of the collimator and crystal was analogous to that described previously in [1]. In all, three sources with activities of 1.38, 1.0, 0.29 mCi were prepared. The activity was determined with the aid of an end-window counter following a method proposed in [2] with allowance for the absorption and scattering of beta particles in the source itself (the accuracy of the activity measurements was ±10%). The sources were placed in a chamber made of polystyrene which was evacuated to about 1 mm Hg. The presence of such a pressure made it possible to neglect the external bremsstrahlung due to the air. The beta particles emitted by the source were completely absorbed by a beryllium absorber placed half-way between the source and the crystal. Such a geometry excludes the incidence of scattered gamma quanta on the phosphor and also insures that the gamma quanta fall on the central part of the crystal.

The measurement of the internal bremsstrahlung spectrum was initially carried out with two sources, and for one year control measurements were carried out with the same sources and measurements with a third source. Three series of measurements were performed with each source. The experimental data of individual series of one source and also of those of different sources with account of the difference in the activities and natural decay coincided within the limits of statistical accuracy.

The spectrometer was calibrated by using the gamma lines of $Hg^{203}$ (279 keV), $Ta^{182}$ (220 and 67.7 keV), $Ce^{141}$ (145 keV), and by using the 75- and 29-keV x-ray lines. The energy graduation and channel width was checked before each reading.

Considerable attention was paid to the radiochemical purity of the sources. Purity measurements were carried out using the maximum possible solid angle. In all sources the observed gamma lines had energies and intensity time variations such as to identify them as belonging to $Ba^{131}$ with a half-life of 12 days. The contribution of these lines to the investigated energy range was taken into account.

The background intensity was determined with the required accuracy before and after each measurement.

The obtained experimental momentum distribution was corrected for background, radioactive impurities, the external bremsstrahlung from the beryllium absorber and from the source itself, the energy resolution of the spectrometer, for the loss of the characteristic x-ray quanta of iodine from the crystal, for the gamma-quantum registration efficiency of an NaI(Tl) crystal of the given thickness, for the absorption of gamma quanta in the source, beryllium absorber, crystal packing, and the shield covering the photomultiplier, for the spectrum of recoil electrons, for the back scattering of gamma quanta by the photomultiplier window, and for the decay rate. The above corrections were introduced to the experimentally observed spectrum following the method of Liden and Starfelt,[3] except for the correction for the loss of the characteristic x-ray quanta of iodine from the crystal which we adopted from the work of Novey,[4] since our geometry of the experiment and the crystal dimensions were identical. The momentum distribution of the $Ca^{45}$ beta particles was taken from [5].

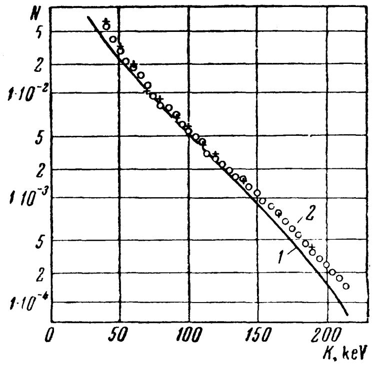
An estimate showed that the errors introduced in correcting for various energies of the internal bremsstrahlung spectrum are as follows:

| Energy, keV | 40 | 70 | 110 | 150 | 200 |
|---|---|---|---|---|---|
| Total error, % | 5.5 | 6.5 | 8 | 9 | 10 |
| Statistical accuracy, % | 1 | 1 | 1.5 | 2 | 3 |

The statistical accuracy and the error in the determination of the activity are not included in the total estimate of the error.

After taking into account all the corrections, we plotted the dependence of the number of internal-bremsstrahlung photons N, per decay and for an energy interval of $mc^2$, on the photon energy in the range from 40 to 215 keV. The experimental points and the curve calculated from the theory of Knipp and Uhlenbeck,[6] and Bloch[7] for allowed transitions are shown in the figure in which the statistical error of the measurements does not exceed the size of the points.

A comparison of the experimental and theoretical curves indicates that in the interval from 60




Internal bremsstrahlung spectrum accompanying the beta decay of $Ca^{45}$: 1 – curve calculated from the theory of Knipp and Uhlenbeck (Z = 0); 2 – experimental points (o – initial measurements, + – control measurements).

to 300 keV the experimental points almost coincide with the theoretical values; however, at higher energies there is no such agreement and the experimental values are higher than those calculated theoretically. For example, the absolute values of the ordinates of the experimental points in the region of 180 keV are 25% higher than the values given by the theory; at 215 keV they are 35% higher. This difference exceeds the experimental errors. The observed rise of the experimental points at energies of 40—60 keV can be explained by the contribution from the x-ray peak of iodine which we have not taken into account.

We have not calculated the curve which takes account of the Coulomb effect. However, if we consider other work on internal bremsstrahlung in which this effect was taken into account (for example, for $S^{35}$ [8]), then it can be assumed that allowance for it in our case would raise the theoretical curve in the high-energy region by no more than 10—15 percent which would improve the agreement but would not bring the curves to coincide.

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Translated by Z. Barnea
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