On the Efficiency of γ-Ray Counters

The efficiency curve for γ-ray counters (efficiency defined as the ratio of the number of incident quanta to the number of registered quanta) is a valuable key for the interpretation of every counting experiment involving γ-rays, but a careful determination of such curves meets with some difficulty. It implies an accurate knowledge of the number of quanta emitted in some transformations, but only a few (if any) energy-level schemes involving γ-rays are quite definite at present. The coincidence method is one of the best ways of testing such schemes, but it, in turn, makes use of efficiency curves. Because of the low efficiency of γ-ray counters, whereby counting experiments often become laborious, it is also of interest to see whether different materials show different efficiencies.

Counters of brass, aluminum and lead, all of the same geometric size (effective length 6 cm, inner diameter 1.4 cm, wall thickness 0.2 cm), have been compared (Fig. 1).

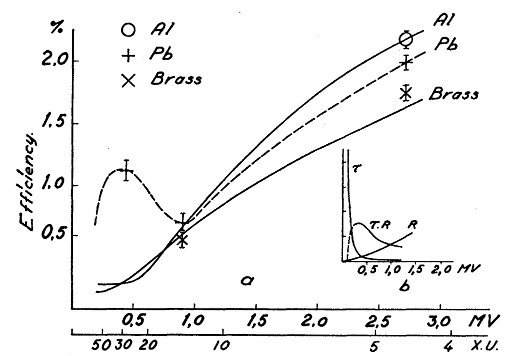

FIG. 1. Comparison of efficiency of counters of different materials.

The curve for brass was published by Droste,[1] who measured the end points and estimated the form semi-empirically; it was recently verified also by Dunworth.[2] Yukawa and Sakata[3] have calculated the *shape* of the Al curve. The point reported here for 2.7 Mev will thus fix this curve. The measurements at 2.7 Mev were made by a radio-thorium source of known strength (ThC$''$ γ-rays, filter 2.5 cm Pb). Points on the Pb and Al curves at about 0.9 Mev were determined by $\beta-\gamma$-coincidence measurements of *Mn^{56} with the source surrounded by a 0.24 g/cm^2 brass filter to eliminate the low energy β-group. According to Curran, Dee and Strothers[4] the high energy β-group should be coupled chiefly to a 0.9-Mev line. At still lower energy *Au^{198}, having γ-components of 0.28 Mev and 0.44 Mev,[5] was used. The $\beta-\gamma$-coincidence rate corresponds to an efficiency of about 1.1 percent for the 0.44-Mev line, if the β-spectrum is simple, which is plausible. In any case the efficiency of the lead counter for the 0.44-Mev line was about 5.6 times greater than the efficiency of the brass counter (after correcting for absorption). This fact, which must be related to the large photo-effect in lead at these energies (see Fig. 1*b* where τ is the photoelectric absorption coefficient, R the range of photo-electrons), makes the lead counter very effective in the region of 0.5 Mev, where the other counters have low efficiency. Therefore, a brass counter with thin lead foils on the inside probably should be most useful. For RaC γ-rays, filtered through 2.5 cm Pb, ($\sim$2 Mev) the relative efficiencies were: Pb$=100$, brass$=84\pm4$, Al$=109\pm4$, and for unfiltered Ra γ-rays correspondingly: Pb$=100$, brass$=67\pm3$, Al$=75\pm3$.

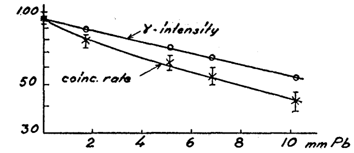

FIG. 2. Comparison of absorption of γ-rays and coincidence rate.

It may be pointed out, that a γ-component in favorable cases (highly different absorption coefficients of the components) can be correlated to other particles without use of an efficiency curve by measuring the decrease of the coincidence rate when absorbers are inserted in front of the γ-ray counter. It seemed worth while to try this method in the important case of *Mn^{56} above. In Fig. 2 the upper curve is a simple absorption curve (Pb-counter), whereby the bad geometry may be taken into account. The coincident rate curve below it (β-filter 0.24 g/cm^2 brass) gives some support to the assumption of Curran, Dee and Strothers, that the most energetic β-particles are coupled to the soft γ-component, but the curve is not quite conclusive, since a still softer γ-component of low intensity (possibly "Bremsstrahlung") seems to be present.

Because of the higher effectivity of obliquely incident rays the coincidence measurements have been reduced to a "large distance" between source and counter by a distance function:

$$\Psi\frac{R}{\pi b}F(x,\,k) \tag{1}$$

and not by the relative space angle, approximately given as:

$$\Phi=\frac{l}{\pi}\arctan\frac{R\cdot l}{[bc(l^2+4bc)]^{\frac{1}{2}}} \tag{2}$$

($2R$ internal diameter, a the distance from source to counter axis, F elliptic integral of first kind, l effective counter length, $x=\arctan\,(l/2c)$, $b=a+R$, $c=a-R$, $kb=(b^2-c^2)^{\frac{1}{2}}$.) The difference between these formulas is appreciable only for small distances such as are common in coincidence experiments. For high γ-energy and light elements the formula (2) should be best (Compton recoil forward).

A more detailed account will be published later elsewhere.

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