TECHNICAL PAPERS

Effect of Absorber Position on Counting Rate of Collimated and Uncollimated Beta and Gamma Radiation[1]

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Although it is generally recognized that, because of scattering effects, the observed counting rate of a radioactive sample depends on the atomic number and geometrical arrangement of absorbers and surrounding material (e.g. *1–9*), we do not know of any published data which show how greatly the counting rate may depend on the position of an absorber foil placed between a fixed sample and detector. The data of Tables 1 and 2 illustrate this dependence and the fact that a variation in absorber position in a collimated beam of radiation may have an effect opposite to that of a similar variation in position in uncollimated radiation. These effects may be explained with the aid of the schematic diagram given in Figs. 1 and 2.

TABLE 1

EFFECT OF POSITION OF ABSORBER ON THE COUNTING RATE OF UNCOLLIMATED RADIATION FROM A RADIOACTIVE SAMPLE

Test*	Type of radiation	Absorber	†Distance (cm) of bottom of absorber from: Sample	G-M tube window	Cpm*
1	Beta, 1.69 Mev, max.	109 mg/cm² of Pb	0	5.4	3,712
			1.5	3.9	3,200
			3.0	2.4	2,528
			4.5	0.9	1,856
2	Beta, 1.69 Mev, max.	120.7 mg/cm² of Al	0	5.4	6,368
			1.5	3.9	5,568
			3.0	2.4	4,512
			4.5	0.9	4,288
3	Gamma, 1.3 Mev and 1.1 Mev	920 mg/cm² of Pb	0	5.4	2,052
			1.5	3.9	1,577
			3.0	2.4	1,377
			4.5	0.9	1,134
4	Gamma, 1.3 Mev and 1.1 Mev	870 mg/cm² of Al	0	5.4	2,040
			1.5	3.9	1,557
			3.0	2.4	1,318
			4.5	0.9	1,233

* Different radioactive samples and different Geiger-Müller tubes were used in different tests, so the relation of the absolute counting rates of different tests has no significance.
† Fig. 1.

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In the case of the collimated beam (Fig. 2) a certain fraction of the radiation, represented by A, is transmitted through the absorber without scattering regardless of the position of the horizontally placed absorber between the sample and the detector. The remaining radiation is scattered with an angular distribution which is independent of the distance of the absorber from the detector window, but the fraction of such radiation entering the window is dependent on this distance. This is illustrated by the radiation labeled B_I, which is scattered from an absorber in position I at such an angle that it does not enter the detector window, while the identical radiation, B_{II}, scattered at the same angle from an absorber in position II, does enter the window.

TABLE 2

EFFECT OF POSITION OF ABSORBER ON THE COUNTING RATE OF COLLIMATED RADIATION

Test*	Type of radiation	Absorber	†Distance (cm) of bottom of absorber from: Lead block	G-M tube window	Cpm*
1	Beta, 1.69 Mev, max.	50.7 mg/cm² of Pb	1.5	5.8	312
			3.0	4.3	425
			4.5	2.8	661
			6.0	1.3	1,045
2	Beta, 1.69 Mev, max.	120 mg/cm² of Al	1.5	5.8	369
			3.0	4.3	491
			4.5	2.8	737
			6.0	1.3	1,185
3	Gamma, 1.3 Mev and 1.1 Mev	465 mg/cm² of Pb	1.5	5.8	672
			3.0	4.3	672
			4.5	2.8	704
			6.0	1.3	832
4	Gamma, 1.3 Mev and 1.1 Mev	445 mg/cm² of Al	1.5	5.8	704
			3.0	4.3	720
			4.5	2.8	736
			6.0	1.3	848

* See Table 1.
† Fig. 2.

When the radiation is not collimated (Fig. 1) the effect illustrated in Fig. 2 still occurs for those radiations in the direct cone of the solid angle subtended by the counter window, but a larger effect, due to the decrease in the total amount of radiation intercepted by the absorber as it is moved from the sample toward the detector, is superimposed. This is illustrated by the radiation labeled C_{IV}, which escapes the absorber and counting tube completely when the absorber is in position IV but which has a certain probability of being scattered along the direction C_{III} and entering the detector if the absorber is in position III.

The effect of absorber position depends, of course, upon area and thickness of the absorber, energy of the radiation, and degree of collimation of the beam. Under some conditions a minimum in the counting rate may occur as the absorber is moved from the sample toward the detector. A specialized case of the effect illustrated in Fig. 1 is the "self-focusing" which often leads to an initial increase in counting rate of a radioactive sample of constant disintegration rate as it is diluted with inactive material.

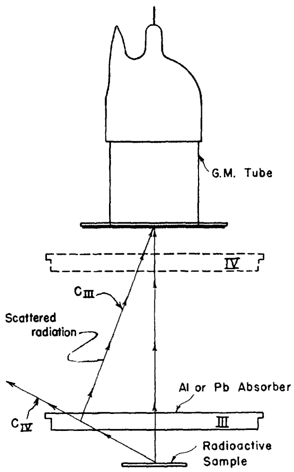

FIG. 1. Illustration of the effect of the position of an absorber on the counting rate of uncollimated radiation.

A radioactive sample mounted as in Fig. 1 gives a lower counting rate through a pile of thin absorbers placed loosely on top of the sample than through a single thick absorber of the same total surface density. For example, when an 1,850 mg/cm² lead absorber in uncollimated gamma radiation from Co^{60} was replaced by 5 single absorbers of thicknesses 916, 434, 234, 234, and 36 mg/cm² totaling 1,854 mg/cm², the counting rate fell from 1,260 cpm to 924 cpm. This is presumably due to the greater average distance from the sample of the absorbing material in the loosely piled absorbers and a consequent decrease in scattering of the type illustrated in Fig. 1.

Since most radioactive tracer work requires only a knowledge of the relative counting rates of samples which can be counted under nearly identical conditions, the phenomena discussed here need not be a serious handicap in such investigations.

The data of Table 1 were obtained using an unshielded, brass, bell-shaped, Geiger-Müller counter tube mounted in a conventional Lucite stand provided with slots for reproducibly placing samples and absorbers. The $1\frac{1}{8}''$-diameter mica window of the tube was 5.4 cm from the radioactive sample spread on a 1″ watch glass resting in a cardboard holder, the backing of which was the wooden desk. The data of Table 2 were obtained in the same manner, except that the radioactive sample was placed at the bottom of a hole 1.5 cm in diameter and 15 cm long in a lead block. The distance from the counter window to the top of the lead block was 7.3 cm, and the geometrical relationships were such that the diameter of the collimated beam of radiation at the counter window was less than the diameter of the window.

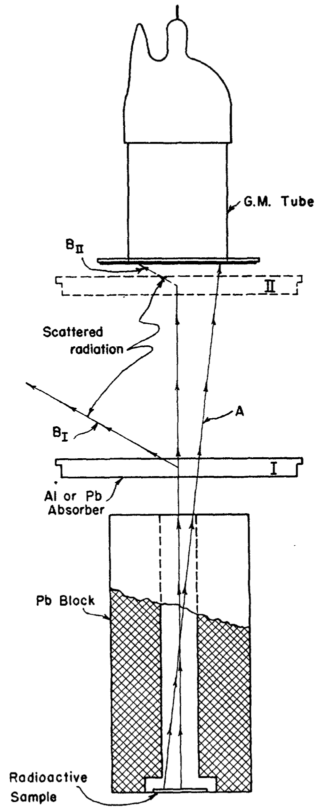

FIG. 2. Illustration of the effect of the position of an absorber on the counting rate of collimated radiation.

Tests of the effect of absorber position on the counting rate were made with both aluminum and lead absorbers ($2\frac{1}{2}'' \times 3\frac{1}{4}''$ in area) with both the beta radiation of P^{32} (1.69 Mev, max. energy) and the gamma radiation of Co^{60} (1.1 and 1.3 Mev). The absorbers used were thick enough to cut out the 0.3-Mev Co^{60} beta radiation.

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