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SCIENCE AND THE STUDY OF MANKIND

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tions which appear when the system goes into oscillation, the parallel is evident. Here, as for the familiar oscillator, a threshold condition exists, and once it is satisfied the starting of the new oscillations, and their phases, are dependent on some disturbance, however small.

If, then, it were found possible to describe atomic transitions as the initiations of oscillations of this type in a Newtonian system, the associated disturbances might produce significant effects only at the transitions. Their effect could then be adequately taken into account by assigning probabilities to the transitions and treating the system as non-Newtonian. (This of course leaves open the question as to whether the behavior of the system between transitions can be described in Newtonian terms.)

Recently, however, it has been found desirable to assume the existence of a randomly fluctuating electromagnetic field in free space, of such magnitude as to produce a small but not negligible effect on the behavior of the elementary particles. Such a field would be precisely what was assumed in the previous paragraph, and should provide a mechanism for controlling the apparently random transitions.

We arrive then at the conclusion that the fact that it has been found convenient to describe atomic phenomena in terms of a non-Newtonian system characterized by certain probabilities of transitions does not in itself constitute evidence that the system in its detailed behavior does not conform to Newtonian laws.

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An Analysis of Multiple Counter Technique for the Measurement of Radioactive Sources Independent of Geometry

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This discussion is concerned with the mathematics of a system of multiple Geiger-Müller counters for the measurement of radiations from a point source within the area bounded by the counters. Graphs are presented from which an area giving any desired accuracy of measurement can be determined.

Similar multiple counter techniques (1, 2) have been used by others over the past several years and offer considerable promise for precise physical, medical, and biological measurement.

A sketch of the apparatus is given in Fig. 1.

For the purpose of analysis the following assumptions are made regarding the geometry, source, and counters.

<sup>1</sup> The authors wish to acknowledge the counsel, during discussions, of Dr. A. K. Solomon, Biophysics Laboratory, Harvard Medical School. They also wish to acknowledge the work of P. J. Edwards, who performed the computations.

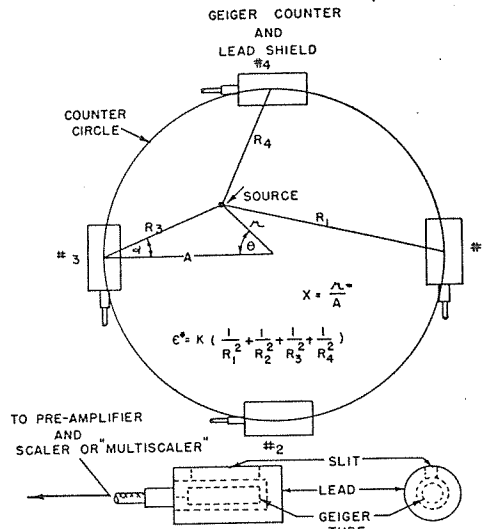


FIG. 1. Sketch of multicounter and lead shield.

1. The radiation is emitted uniformly in all directions about the source. There is no absorption in the medium between the source and counters; or the absorption is uniform in all directions.

2. The efficiency of the counter is proportional to the solid angle subtended at the source by the Geiger counter cathode, and the solid angle is inversely proportional to R<sup>2</sup>, where R is the distance from the source to the center of the counter cathode.

3. The efficiency of the counter is independent of angle alpha between the normal to the counter cathode and the line from the source to the center of the cathode.

4. All counters have identical counting characteristics (plateau and efficiency).

5. The source is a point.

6. The region of interest is limited to the plane containing the centers of the four counters.

Under these assumptions the analysis is reduced to eval-

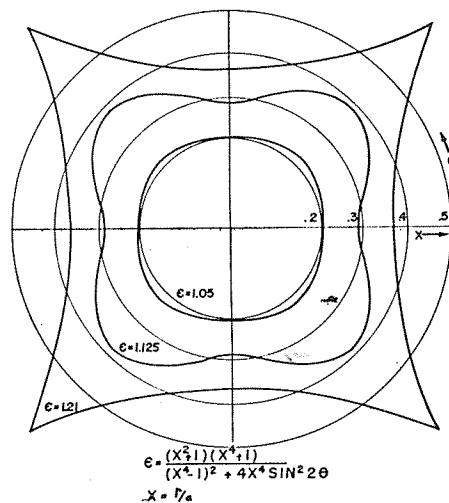


FIG. 2. Efficiency contours: x versus theta for constant epsilon (theoretical).

uating the sum of  $1/R^2$  factors over all four counters for a source position within the circle passing through the four counters. This yields the following expression for the counting efficiency  $\epsilon^*$ :

$$\epsilon^* = \frac{K(x^2 + 1)(x^4 + 1)}{(x^4 - 1)^2 + 4x^4 \sin^2(2\theta)} \quad (1)$$

where

$$x = \frac{\mu}{A} = \frac{\text{Distance of source from center of counter circle}}{\text{Radius of counter circle}}$$

and  $K$  = a constant of proportionality containing such factors as the solid angle subtended at the center by the counters, and the energies of the gamma radiation emitted by the isotopes being measured. By considering the relative efficiency  $\epsilon$  (compared to the efficiency  $\epsilon_0$  at the center of the counter circle), the constant  $K$  can be eliminated and the following expression results:

$$\epsilon = \frac{\epsilon^*}{\epsilon_0} = \frac{(x^2 + 1)(x^4 + 1)}{(x^4 - 1)^2 + 4x^4 \sin^2(2\theta)} \quad (2)$$

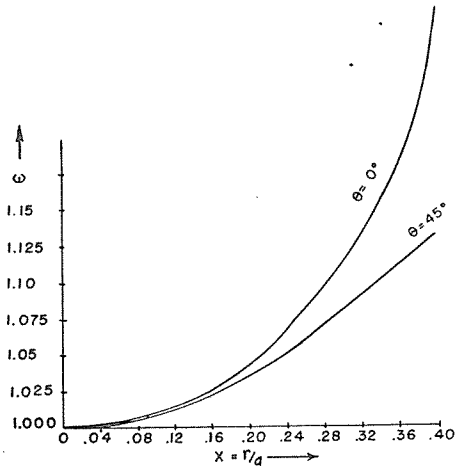


FIG. 3.  $\epsilon$  versus  $x$  (theoretical);  $\epsilon$  and  $x$  same as of Figs. 2 and 4.

Solution of equation (2) for  $x$  as a function of  $\theta$  at constant values of  $\epsilon$  yields the curves shown in Fig. 2. For  $\epsilon = 1.05$ , i.e., for an efficiency 5% greater than the efficiency at the center of the counter circle, the curve is approximately a circle of radius very nearly one-fifth the radius of the counter circle ( $x = 0.2$ ). Curves for higher efficiency are also given and are seen to lie outside the curve for  $\epsilon = 1.05$ . Thus, within this latter curve the efficiency is nowhere greater than 5% higher than the efficiency at the center.

In Fig. 3 are shown curves of  $\epsilon$  as a function of  $x$  at two values of  $\theta$  ( $0^\circ$  and  $45^\circ$ ). The curve of  $\theta = 0^\circ$  (directly at one of the counters) is seen to rise much more rapidly than the curve for  $\theta = 45^\circ$  (halfway between two counters).

In Fig. 4 are shown curves of  $\epsilon$  as a function of  $\theta$  for several values of  $x$ . These curves quite describe the apparatus as defined or limited by the assumptions made above.

With regard to the variations of  $\epsilon$ , it is of value to note that these are all positive and that the variation over a

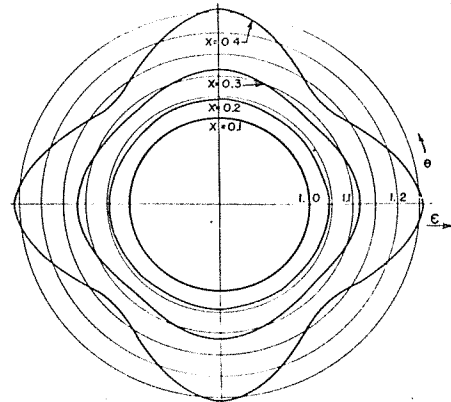


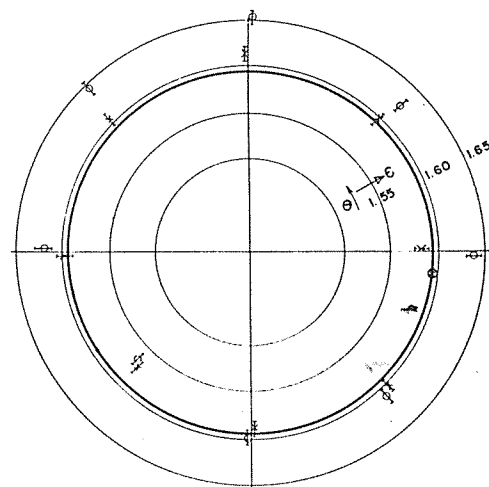
FIG. 4.  $\epsilon$  versus  $\theta$  (theoretical);  $\epsilon =$  relative efficiency compared to efficiency at center.

distributed source is therefore generally less than that indicated by the smallest curve of Fig. 2 or Fig. 4 that fully contains the source.

Also, one should note that assumption 3 listed above is probably not fully justified when accurate measurements are being made. Consideration of the variation of  $\epsilon$  with  $\alpha$ , for the type of counters and shielding used, indicates that considerably smaller variations of  $\epsilon$  may be expected than those indicated by the above analysis.

For the accuracy desired (better than 5%) it is also essential to make corrections for the counting losses incurred by the "dead time" of the Geiger counters when the counting rates are greater than a few thousand per minute. Note, however, that these losses are smaller by a factor of 4 at any given counting rate because of the use of four Geiger counters.

An apparatus described by the analysis above was assembled, and a series of measurements were made to de-



⊙ •  $\epsilon_0$  = CENTER EFFICIENCY = 1.5934  $\pm$  0.003<sub>3</sub>  
 † • EFFICIENCY AT  $x = 0.1$ , AVE. = 1.5957  $\pm$  0.001<sub>6</sub>  
 ‡ • EFFICIENCY AT  $x = 0.2$ , AVE. = 1.619<sub>6</sub>  $\pm$  0.001<sub>6</sub>  
 $\Delta$  = 1.619 - 1.593 = .026  $\pm$  .004  $\approx$  1.6%

FIG. 5.  $\epsilon$  versus  $\theta$  (experimental).

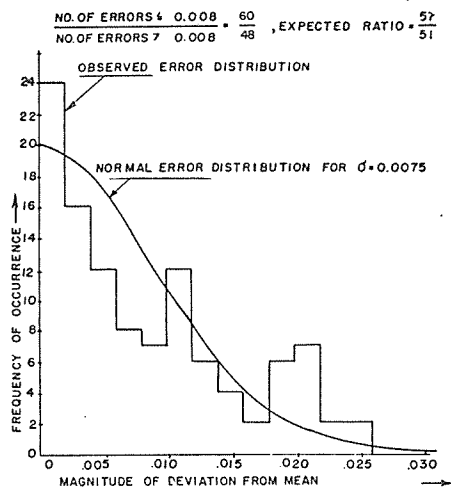


FIG. 6. Statistical summary of data.

termine its usefulness. A radium source was used and the counting rate, i.e., the efficiency in arbitrary units, was measured at the center of the counter circle and at several values of  $\theta$  for each of two values of  $\alpha$ . The results are shown plotted in Fig. 5, with arbitrary units for the  $\epsilon$  scale. The bold circle drawn in indicates the value of  $\epsilon_0$  at the center of the counter circle, and it is seen that no value of  $\epsilon$  differs from this center value by as much as 5%, indicating the validity of the analysis. Also, the average value of  $\epsilon$  over all the measurements taken at the greatest value of  $\alpha$  (0.2) is less than 2% greater than the center value, and the average value of  $\epsilon$  over the smaller value of  $\alpha$  (0.1) is practically the same as the center value, i.e., within the probable statistical error of the measurements. These averages are more significantly related to the measurements of distributed sources than are the single measurements made at particular values of  $\theta$ . That these averages are appreciably smaller than the 5% that might have been expected is probably due to the variation of  $\epsilon$  with  $\alpha$ . This, by assumption 3 above, is assumed to be insignificant. At large values of  $\alpha$  this variation is further increased by the thick lead shield whose slit exposes the counter to the source in a variable manner as  $\alpha$  varies.

The probable statistical error of the measurements is considerably smaller than the observed variations. The asymmetry observed in Fig. 5 is almost certainly owing to the fact that one of the counters in this run of measurements does not have the same characteristic as the other three and therefore is counting at a higher rate. Fig. 6 shows the summary of a statistical analysis of the data, and it can be seen that the distribution of the statistical deviations of the measurements is in reasonable agreement with a normal error curve, as taken from the *Handbook of Chemistry and Physics* (30th Edition, pages 203-208).

It is expected that with this apparatus measurements of radiation dosage can be made to an accuracy approaching a few percent, subject to variations of absorption that may occur from one (human) sample to the next. We are attempting to determine the uncertainty to be ex-

pected from the greater absorption presented by the patient's neck to the counters behind the neck. Since the body is mostly matter of low atomic number, we expect the absorption will be low and very probably negligible for clinical purposes. We are also investigating the magnitude of the variation of  $\epsilon$  with height of source above or below the plane of the four counters.

In a subsequent communication we plan to report upon this latter aspect and upon the clinical appraisals of the apparatus herein described.

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### Isolation of a Steroid Hormone from the Adrenal-Vein Blood of Dogs<sup>1</sup>

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Lipid soluble material which protects adrenalectomized animals against cold has been demonstrated by Vogt (5) in blood obtained by cannulation of the adrenal vein of dogs. From the same source Paschkis *et al.* (3) have also found material causing liver glycogen deposition. As is well known, various active steroids have been isolated from adrenal tissue (4). According to the recent work of Haines *et al.* (1), the most abundant of these in fresh adrenal tissue is 17-hydroxycorticosterone (Kendall's compound F). The actual compound or compounds excreted by the adrenal cortex when stimulated by the pituitary adrenocorticotrophic hormone have not, however, been identified. The development of a quantitative technique for estimation of cortical steroids in adrenal-vein blood (6) enabled us to isolate a steroid from this source.

The left adrenal vein of heparinized dogs, anesthetized with nembutal, was cannulated. The dogs were then injected with Armour's ACTH<sup>2</sup> and blood was collected at intervals for 2-4 hr. In some cases a second injection of ACTH was then given and the collection of blood continued as before.

The blood was diluted with an equal volume of water and extracted four times with an equal volume of ethyl ether or chloroform. These extracts were evaporated to dryness, taken up in 70% ethanol, and extracted three times with hexane. The ethanol fraction was dried, dissolved in chloroform, and chromatographed on a magnesium silicate-celite column, using progressively increasing concentrations of ethanol in chloroform. A small

<sup>1</sup>This study was supported by grants from the National Cancer Institute, U. S. Public Health Service; the American Cancer Society; and Ciba Pharmaceutical Products, Inc.

<sup>2</sup>The ACTH was supplied through the courtesy of Dr. Edwin E. Hays and Dr. F. R. Mote of Armour and Company.