For comparison with individual data presented by Zimmerman and collaborators, Table 5 presents the gains in I.Q. for the 3 individuals in each group showing maximum gain.

TABLE 5

GAINS IN I.Q. FOR THREE INDIVIDUALS IN EACH GROUP SHOWING MAXIMUM GAIN FROM 9/47 TO 6/48

Experimental group				Control group			
Subject	I.Q. 9/47	I.Q. 6/48	Gain	Subject	I.Q. 9/47	I.Q. 6/48	Gain
Em	74	95	21	Ma	57	76	19
Bu	51	62	11	Mo	51	68	17
Cu	44	55	11	El	63	75	12

The results presented above provide strong support for the hypothesis that controls in Zimmerman's experiment were inadequate. Our control group showed significant gains in I.Q. that did not differ significantly from those in the experimental group. The present experiment gives no evidence concerning the cause of these gains, but it may be suggested that a bias in test scoring, which was apparently not controlled in the earlier experiment, may have been operative. In the Indiana study another variable may be mentioned. The teachers at the school were greatly interested in the experiment. Consequently, the stereotyped institutional life of the subjects was very probably livened up by extra attention. The subjects in both groups also made two trips a day to the school kitchen. This additional stimulation may have produced some effect on test scores. Zimmerman and his collaborators do not report their procedure in sufficient detail to indicate whether extra stimulation was present in their study.

The mean gain in I.Q. reported for the retarded group in the Zimmerman study was greater than in the present one. However, when gains in the retarded group are corrected for regession as estimated, they are approximately the same as were found in the Indiana experimental group. It seems likely that, if bias affects test scores, the effect would be greater in the Zimmerman experiment provided we can assume that the psychometrists knew that the subjects were receiving glutamic acid. In the Indiana experiment the psychometrists knew that only half the subjects were receiving this treatment.

Although extreme gains in individual scores are not acceptable evidence when variable measures are used, it is of interest, though not surprising, that gains comparable to those reported in the appendix to Zimmerman's study were also found in the Indiana study (Table 5). Comparable extreme gains appear in both the experimental and the control groups.

The significant difference in time taken for star-tracing in the coordination test is in apparent agreement with animal studies (*1, 2*), which have shown greater activity following administration of glutamic acid. The significantly poorer error performance of the experimental group is probably related to the difference in time.

If tapping rate may be considered a measure of maximum rate of response, it is of interest that this was not significantly different in the two groups.

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The Measurement of Radioactive Hydrogen in Solid Samples—Comparison with Gas Counting[1]

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Radioactive hydrogen has been measured as hydrogen gas, or a volatile compound containing hydrogen, inside Geiger-Müller counters and ionization chambers (*1, 2, 4, 6*). The experiments reported below demonstrate that solid compounds, suitably plated out on a sample pan and using a windowless counter, can be measured with satisfactory precision. The principal disadvantage of the solid-counting procedure arises from the extremely weak energy of the β particles emitted by radioactive hydrogen, leading to an infinite thickness of less than one mg/cm^2. The most important advantage is the elimination of the time-consuming steps in the gas-counting measurement: the quantitative combustion of the sample and complete conversion[2] of the resulting water into hydrogen gas. Additional time is consumed in the preliminary "seasoning" of the combustion-conversion train to avoid isotopic contamination. Further, the compound is not destroyed during the analysis. Consequently, it is expected that solid-counting techniques will be a valuable complementary tool in radioactive hydrogen tracer studies, including paper chromatographic and radioautograph techniques.

The compound selected for study of solid-counting was methyl-3-α-acetoxycholinate containing radioactive hydrogen in the 11 and 12 positions. This compound, obtained in the course of a steroid tracer project, was made by the hydrogenation of the $\Delta^{11,\ 12}$ cholenate in an acetic acid medium containing radioactive hydrogen, with the use of a platinum oxide catalyst. It was purified by repeated addition and removal of inactive solvent and was recrystallized three times from petroleum ether (60° C). The melting point was 134.5° C.

The solid was directly plated on aluminum pans having an area of approximately 10 cm^2. A solution of the

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[2] Incomplete conversion results in isotopic fractionation and leads to incorrect analyses.

compound in acetone was added to the pans, which were then placed on a steam-heated plate. During this evaporation step the solution was spread over the entire surface by means of a glass rod scrubber. After the compound had separated out in a fairly uniform thin layer, the traces adhering to the side of the shallow pans were carefully removed.

The plated pans were placed in a positioned slot under a windowless methane-flow type counter operating in the proportional region.[3] The background count was approximately 50 cpm and was measured either before or after each point plotted in Fig. 1.

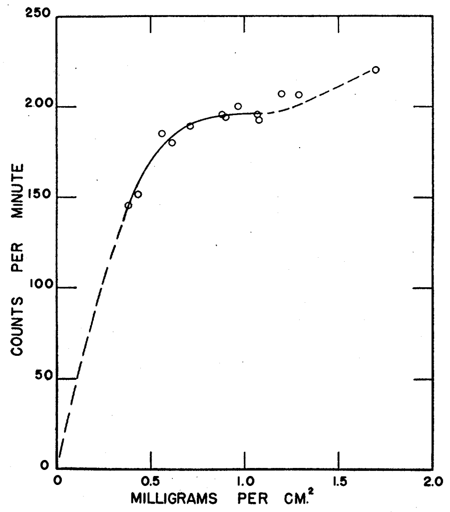

FIG. 1. Counting rate vs. thickness of sample. Solid-counting curve for methyl-3-α-acetoxycholinate (radioactive hydrogen in the 11 and 12 positions).

The counts per minute, corrected for background, are plotted in Fig. 1 as a function of the mg of steroid/cm^2. After the initial rapid rise there is a leveling off between 0.8 and 1.1 mg/cm^2. Beyond this thickness and up to at least 1.7 mg/cm^2, the observed counting rate slowly rises. The 5 points that correspond to thicknesses between 0.8 and 1.1 mg/cm^2 average 195.4 cpm, with an average deviation of 1.9, or about 1%.

The probable error in each point caused by the statistics of counting is less than 0.7%. This represents a "practical" infinite thickness counting rate.[4] This interval would be recommended for quantitative determinations of relative activity of the solid compound. Larger crystal formation is observed in the thicker samples, resulting in a slightly augmented or "corrugated" surface and leading to the slow increase in observed counting rate.

Libby (*7*) has given the following empirical range-energy relation for energies up to 200 kev:

$$\text{Range (mg/cm}^2) = \frac{E^{5/3}}{150},$$

where E is the upper energy limit in kiloelectron volts. This equation shows a satisfactory agreement with data using monochromatic electron beams (*8*). Curran, Angus, and Cockcroft (*3*) have recently studied the β-ray spectrum of radioactive hydrogen and have reported an upper energy limit of 17.9 ± 0.3 kev. When this value is substituted in the equation, a calculated range of 0.82 mg/cm^2 is obtained. This is in qualitative agreement with the experiments reported here. At this value of the thickness, the counting rate in Fig. 1 has reached a level-off value.

A comparison of the solid-counting data reported above was made with the highly efficient internal gas-counting method. Several 5-mg samples were combusted, and the water completely converted to hydrogen over zinc at 400° C.[5] The counter tube filling mixture contained 5 cm of hydrogen and 60 cm of methane. The upper portion of the proportional region was used with an amplifier-scaling circuit combination at a discriminator setting of one mv (*5*). The counting efficiency in the sensitive region is very close to 100%. Relative activities obtained in internal gas-counting are reliable to within 1%. The absolute disintegration rate was calculated to be 950 ± 5% disintegrations/min/mg steroid, or 7,600 ± 5% for 8 mg. It is seen in Fig. 1 that an 8-mg sample spread out on a 10-cm^2 pan has approximately reached infinite thickness and furnished an observed counting rate of 195 counts/min. In other words, the observed counting rate from this infinitely thick solid sample measured at close to 50% geometry is only 0.026 of the absolute disintegration rate for 8 mg of this steroid sample.

This comparison of gas- and solid-counting illustrates the complementary nature of each method in biochemical studies. The synthetic steps leading to the preparation of the labeled compound are, in general, carried out at higher specific activity levels in order to compensate for subsequent dilution in metabolic experiments. Solid-counting techniques will be primarily useful here. The extent to which solid-counting can be used to follow the activity of products of metabolism experiments depends, of course, on the extent of dilution. The gas-counting procedures will be generally applicable.

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[3] The Radiation Counter Laboratory, Chicago, Illinois, Nucleometer. At the present time, windowless, flow-type counters functioning as Geiger-Müller and proportional counters are made by several companies.

[4] For accurate knowledge of infinite thickness, the smoothness of the surface becomes increasingly significant when extremely weak β particle emitters are studied. The thickness is usually stated in terms of mg/cm^2, and the area used is the area of the supporting pan.

[5] The combustions and conversions were carried out by Robert W. Jailer, Division of Steroid Biochemistry, Sloan-Kettering Institute.