GEIGER COUNTER
PLOTTING A GEIGER PLATEAU

PROBLEM

To determine the plateau and operating voltage of a Geiger-Müller counter.

INTRODUCTION

All Geiger-Müller tubes do not operate satisfactority at the same voltage because of differences in the construction of tubes.

If a radioactive sample is positioned beneath a tube and the voltage slowly increased from zero, the tube will not start counting until it reaches its starting potential. As the voltage is increased slightly beyond this point, a rapid increase in the count rate takes place. This voltage is known as the threshold. Past the threshold, further increases of voltage result in a negligible increase in counting rate. This region is called the plateau. An operating voltage is selected within the plateau.

To help preserve the life of the tube, the operating voltage is usually selected within the lower 25% of the plateau (near the threshold). If the voltage is further increased past the plateau until another rapid rise of the count rate takes place, the region of "continuous discharge" has been reached. Operating a G-M tube in the continuous discharge region will ruin a tube quickly.

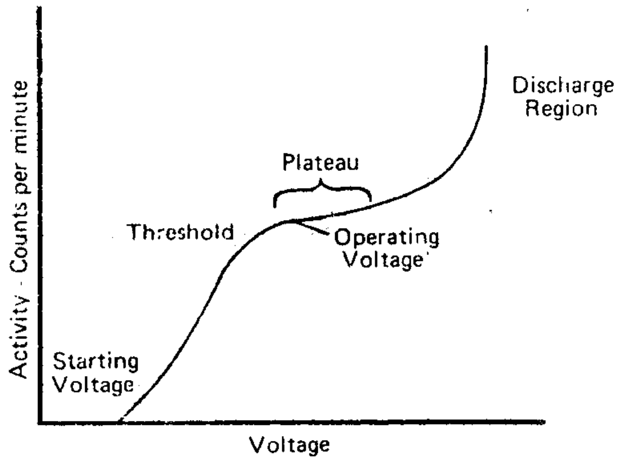


Figure C-1 Typical Geiger characteristic curve

In this experiment, you will find the proper operating voltage after you construct a graph of counts per minute against voltage.

In conjunction with the G-M tube you will use a scaler, which is really nothing more than "an electronic adding machine." The scaler records the counts made by the G-M tube.

APPARATUS

G-M tube, end-window type; tube standard sample holder; scaler; timer

MATERIALS

Prepared mount of ^{204} Tl or other beta emitter.

PROCEDURE

While details of construction vary among different makes and models of scalers, they are all basically similar in operation. The parts of a typical scaler are shown in Figure C-2.

If the scaler is turned off, turn on the master switch and allow three minutes for warm-up. A pilot light is usually found on the instrument panel and indicates whether or not power is being supplied to the scaler.

To prevent a surge of current from flowing through cold tubes, most scalers are not turned off if used more than once or twice a week. The high voltage adjust is always turned down to its lowest position, however, whether leaving the scaler turned on or off, when not in actual use.

Place the prepared beta sample, designated by your instructor, into position on the second shelf of the sample holder. Depress the reset switch. Turn the high voltage adjust to the lowest value on the panel. Turn the count switch to the "on" position. Again check to be sure the high voltage adjust is in the lowest position (completely counter-clockwise) and then turn on the high voltage switch. Let the instrument count for about two minutes.

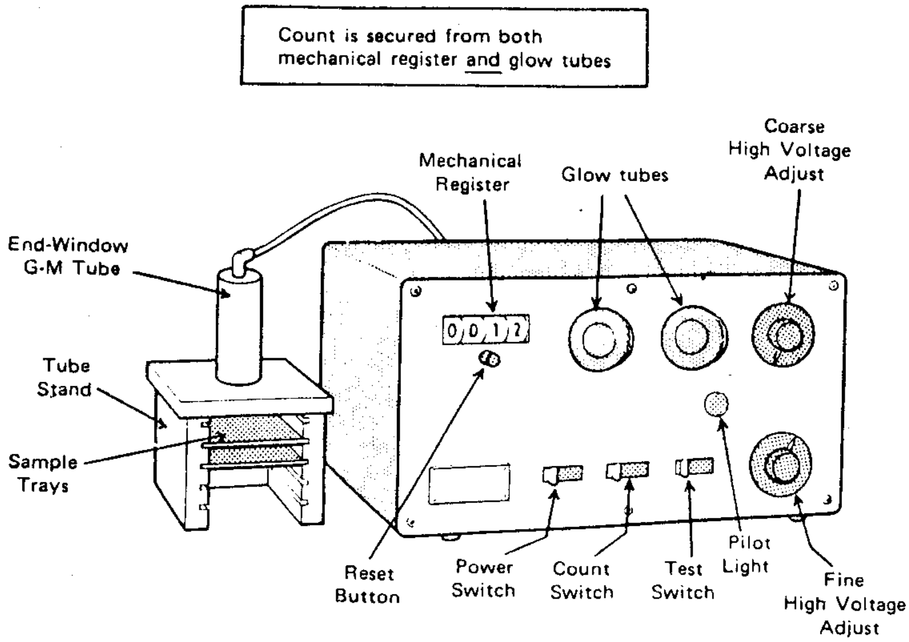


Figure C-2 Typical scaler

Observe and record the number of counts per unit time at various voltages by increasing the voltage in 25 or 50 volt steps. (In order to prevent continuous discharge and destruction of the tube, do not allow the count rate to rise more than 10% above the plateau value.)

After you have finished using the scaler, turn the high voltage adjust to the lowest possible value, but do not turn off the scaler.

DATA

Voltage	Counts	Time	Counts Per Minute cpm

Tube type ____________________

Tube model ____________________

Operating voltage suggested by manufacturer ____________________

Scaler used ____________________

Radioactive source used ____________________

CALCULATIONS

Plot a graph as illustrated in Figure C-1, with counts per minute on the y-axis and voltage on the x-axis.

Determine the best operating voltage for the tube: ________ volts.

RESOLVING TIME

PROBLEM

To determine the resolving time of a G-M counter.

INTRODUCTION

When radiation produces ionization in a Geiger tube, the electrons travel to the anode more quickly than the positive ions travel to the cathode. During the time it takes the positive ions to reach the cathode, the tube is insensitive. During this time a second ionizing ray striking the tube will not be recorded because the tube cannot resolve one from the other. Such a phenomenon is called coincidence.

As a result of coincidence, the observed count is always less than the true count. An approximate correction for coincidence can be made by adding 0.5% per 1000 cpm to the observed count if it is assumed that the resolving time is about 300 microseconds (μsec).

0.5% Correction Per 1000 cpm

Observed Activity r	Thousands of Counts	% Correction	Actual Correction cpm	Corrected Activity cpm R
1000	1.00	0.50	5	1,005
2000	2.00	1.00	20	2,020
6120	6.12	3.06	187	6,307

In this experiment, you will perform a more accurate analysis of dead time, using the method of paired sources. The activities of two sources are measured individually (r_1 and r_2) and then together (r_3). A convenient form for the sources is shown in Figure C-3. It consists of a disc cut in two lengthwise. A small quantity of radioactive material is placed on each half, so that each "half-source" is approximately equal in strength. A blank may be used to preserve the geometry for taking the background count.

APPARATUS

G-M tube and scaler.

MATERIALS

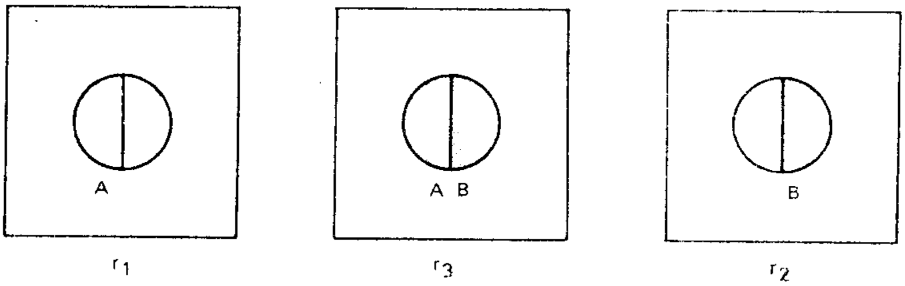
Paired sources.

PROCEDURE

The sequence in which the measurements are made is important as it permits the minimum number of changes and thus ensures a more reproducible geometry.

Place source A in position (with a blank if available) on the sample tray as shown in Figur C-3. Count for five minutes. Calculate the activity in counts per minute (cpm). This count is r_1

Carefully remove the blank and replace it with source B as shown in Figure C-3. Count for five minutes. Calculate the activity in cpm. This count is r_3



Shaded areas represent the source

Figure C-3 Measurement of resolving time by the method of paired sources

Carefully remove source A and replace it with a blank as shown in Figure C-3. Count for five minutes. Calculate the activity in cpm. This is count r_2.

Remove both sources and determine the background. Use blanks if available. This is count r_b

NOTE : If time permits, counting times of ten minutes or longer should be employed to provide more accurate data.

DATA

r_1 ____________ cpm r_3 ____________ cpm

r_2 ____________ cpm r_b ____________ cpm

Resolving time (T) ________ min ________ sec ________ μs

Resolving time specified by manufacturer ________ μs

CALCULATIONS

Compute the resolving time by using this equation :

$$T = \frac{r_1 + r_2 - r_3}{2 r_1 r_2}$$

By use of the resolving time, T, the activity of a sample can now be corrected for resolving time by applying the relation

$$R = \frac{r}{1 - rT}$$

where r is the observed activity and R is the corrected activity.

GEIGER TUBE EFFICIENCY

PROBLEM

To determine the efficiency of a G-M counter for various types of radiation.

INTRODUCTION

From earlier experiments, you may have learned that a G-M counter does not count all the particles which are emitted from a source. Some particles do not strike the tube at all, because they are emitted uniformly in all direction from the source. In this experiment, you will calculate the efficiency of a G-M tube counting system for different isotopes by comparing the count rate to the total disintegration rate.

APPARATUS

Scaler and G-M tube; timer (optional).

MATERIALS

Calibrated sources of the following radioisotopes: ^{204}Tl, ^{133}Ba, ^{14}C.

PROCEDURE

Place a source on the first shelf of the tube stand and determine the activity by taking a five-minute count. Record.

Repeat the above procedure with the other two sources. Record all data.

Determine the background in the same way and record.

DATA

	^{204}Tl	^{14}C	^{133}Ba
Average activity (cpm)			
Background (cpm)			
Corrected activity (cpm)			
Efficiency (per cent)			

CALCULATIONS

Correct all activities for background and resolving time. Calculate the percentage of efficiency for each isotope by using the following formula :

$$\% \text{ Efficiency} = \frac{r(100)}{CK}$$

where r = corrected activity, cpm
C = activity of source, μCi
K = a constant, 2.22×10^6 dpm/μCi

^{14}C emits a "soft" or low-energy beta particle (0.154 MeV), while ^{204}Tl emits a medium-hard beta (0.77 MeV). Which type of beta particle is detected more efficiently, a soft or a medium-hard beta? Can you think of reasons to support your answer?

^{133}Ba emits gamma rays. Compare the efficiency of the G-M counter for beta particles and gamma rays. For which is it more efficient?

QUESTIONS

1. Is the efficiency you calculated for each isotope valid only for that isotope? Explain your answer.
2. If a different shelf is used, will the efficiency change? Explain your answer.
3. How can you increase the efficiency of the G-M tube for gamma rays?

SHELF RATIOS

PROBLEM

To investigate the effect of distance upon the intensity of radiation and to measure the shelf ratios of a sample holder.

INTRODUCTION

Although radiation is emitted from a source in all directions, only a small part actually enters the tube to be counted. This fraction is a function of the distance, h, from the point source of radiation to the G-M tube. See Figure C-4. If the source is moved further away from the tube, the amount of radiation entering the tube should decrease with the square of the distance if the inverse square law applies. (If the source is very close to the window, this relationship does not apply accurately.)

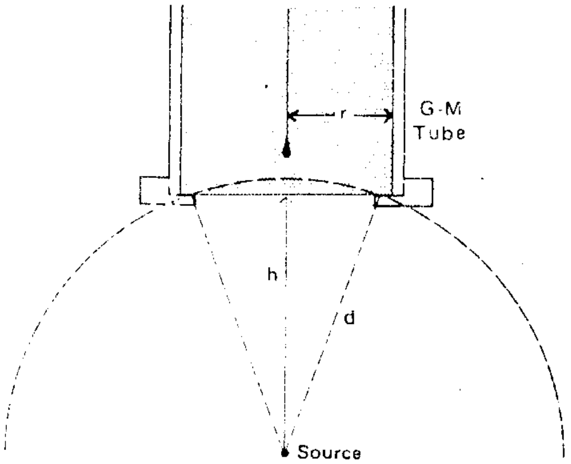


Figure C-4 Influence of source-to-window distance on observed activity.

As a beta source is moved away from the detector, activity will decrease more rapidly than predicted by the inverse square law because beta particles are also absorbed by air.

It is sometimes convenient to take advantage of this change in activity with distance by moving less active samples toward the counter and samples which are too active away from the tube in order to obtain a suitable counting rate. It is for this reason that tube stands are made with adjustable shelves.

It becomes necessary, however, when comparing the activities of two samples not measured on the same shelf, to know the *shelf ratio* so that the activities can be normalized, or compared on equal terms.

APPARATUS

G-M tube and scaler; tube stand; timer.

MATERIALS

Beta sources, ^{32}P or ^{204}Tl and ^{14}C.

PROCEDURE

Take a background count and record. Determine the activity of the ^{32}P sample on the first shelf and record. The first shelf is the one closest to the G-M tube window. The sample should not give an activity of more than 10,000 cpm on any shelf. Record all data in the chart below. Determine the activity of the sample on each succeeding shelf and record.

Follow the same procedure with the ^{14}C sample.

DATA

Source____________________ Max. β energy____________________

Shelf Number	Activity cpm	Corrected Activity cpm	Shelf Ratio
1			
2			1.00
3			
4			
5			
6			
7			

CALCULATIONS

Correct all activities for background and dead time. Assign to shelf #2 a shelf ratio of 1.00. This is the shelf most often used. Calculate the shelf ratio for the other shelves by dividing the activity of shelf #2 into the activity of each shelf.

Does the shelf ratio depend upon the identity of the sample used?

STATISTICS OF COUNTING

PROBLEM

To study methods for increasing the accuracy of measurements.

INTRODUCTION

In the previous experiment, it was shown that the disintegration of radioactive nuclei is a random process which can be predicted with some degree of certainty. In this experiment, you will see how you can decrease the inherent error in the measurement of radioactivity.

APPARATUS

G-M tube and scaler; tube stand; timer (optional).

MATERIALS

Beta source (^{204}Tl, ^{137}Cs, or a uranium salt will do).

PROCEDURE

Place the sample on a suitable shelf so that 1000 to 2000 cpm are obtained. Make 20 observations of one-minute duration. The observations must be made in a continuous series without interruption, and the source, counter, and other conditions must not be disturbed throughout. Each count, n, should be recorded in the table for data.

Repeat by making 20 one-minute observations of the background activity or the activity of a very weak source.

DATA

	Sample #1			Sample #2		
Observation	n	$n-\bar{n}$	$(n-\bar{n})^2$	n	$n-\bar{n}$	$(n-\bar{n})^2$
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
Totals	____A	____B	____C	____A′	____B′	____C′

Sample #1			Sample #2		
$\bar{n}$ =	$A/20$ =	____	$\bar{n}$ =	$A'/20$ =	____
σ =	$\sqrt{\bar{n}}$ =	____	σ =	$\sqrt{\bar{n}}$ =	____
S =	$\sqrt{C/19}$ =	____	S =	$\sqrt{C'/19}$ =	____

CALCULATIONS

Calculate $\bar{n}$, the mean or average value of the 20 individual observed counts, n. To do this determine the grand total of counts A by adding together the individual values of n. Divide A by the number of observations (in this case, 20).

Subtract $\bar{n}$ from each value of n and record in the second column of the previous table. The total of these values, B, should equal zero and serves as a check on your arithmetic. If B is not equal to zero, check your work. B serves no other purpose here.

Square each value of $(n-\bar{n})$ and record these values in the column headed $(n-\bar{n})^2$. Add all values of $(\bar{n}-n)^2$ together to obtain the total C.

Calculate the value of σ. This is found by taking the square root of $\bar{n}$. σ is called the **standard deviation.** If your data are perfectly random, 68% of the observed values of n (i.e., about 13 out of the total of 20 observed values) should lie within the range from $\bar{n}-\sigma$ to $\bar{n}+\sigma$.

Calculate the value of S, the **sample standard deviation.** To do this divide C, the sum of all values of $(n-n)^2$, by 19. Then take the square root of the quotient. (The figure 19 is one less than the number of observations, i.e., $20-1 = 19$. If 25 observations had been made we would have divided by 24.) The sample standard deviation is calculated in such a way that 68% of the data will fall within the range $n-S$ to $n+S$, even if the data are not perfectly random.

If the data are perfectly random, then as the number of observations becomes very large (many more than 20 as in this experiment), the value of S will be closer and closer to the value of σ.

ABSORPTION OF GAMMA RAYS

PROBLEM

To investigate the absorption of gamma rays.

INTRODUCTION

Gamma radiation, unlike alpha and beta radiation, consists of electromagnetic waves. Gamma rays are emitted as photons or little "bundles" of energy called quanta, which travel with the velocity of light c, 3.0×10^{10} cm/sec. The only difference among gamma rays, x-rays, visible light, and radio waves is the wave length or frequency as shown by the diagram of the electro-magnetic spectrum. (Figure C-5). Notice that the zones of differentiation overlap in some areas.

Wave length λ and frequency ν are related to the velocity of light c by the equation

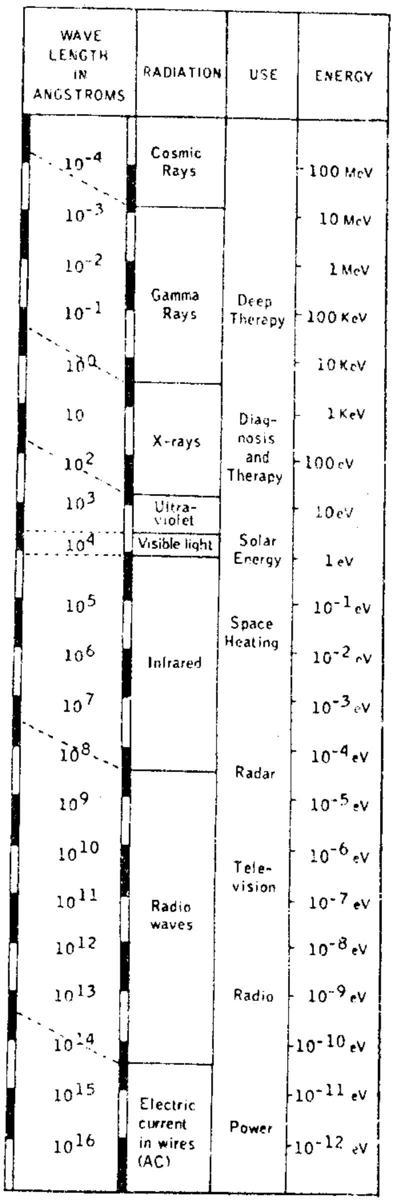


Figure C-5 Electromagnetic spectrum

$$\lambda = \frac{c}{\nu}$$

One significant difference between x-rays and gamma rays is their source. The source of x-rays is outside the nucleus, while that of gammas is within the nucleus. X-rays are produced when electrons undergo deceleration or when an orbital electron jumps from one orbit to another of lesser energy. On the other hand, gamma rays are produced by transitions of energy within the nucleus. Although gamma rays react with matter in a variety of ways, in this experiment we will be concerned primarily with their absorption by matter.

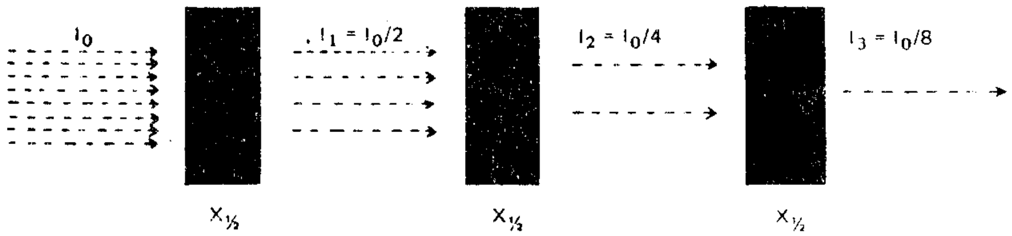


Figure C-6 ATTENUATION OF GAMMA RADIATION. The significance of half-value-layer or half-thickness is illustrated.

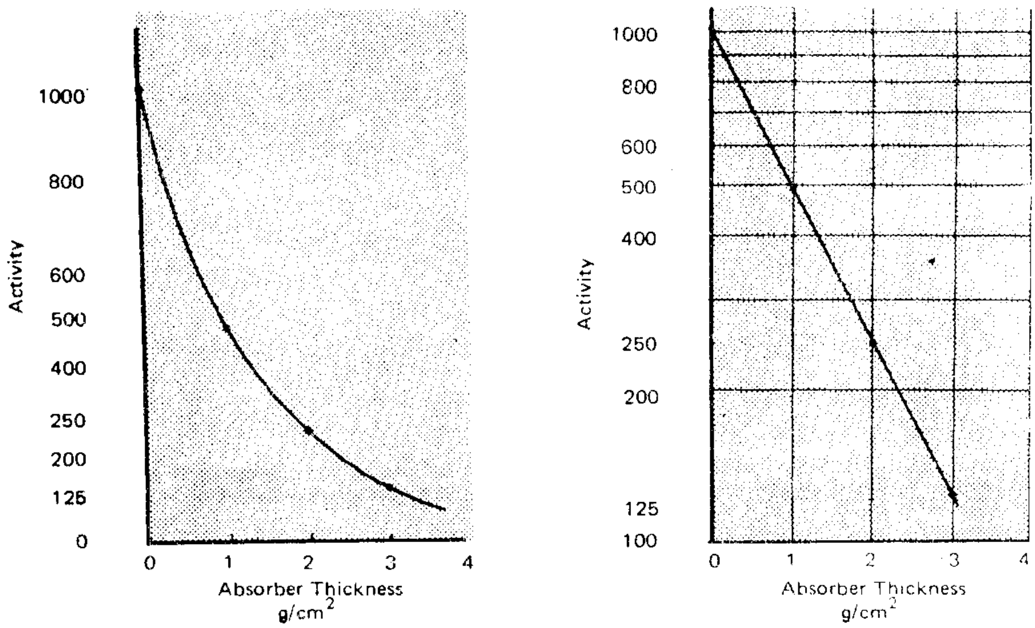


Figure C-7 ATTENUATION OF GAMMA RADIATION. The relationship between activity and absorber thickness is illustrated.

If a beam of gamma rays impinges on a sheet of absorbing material (Figure C-6), some of the radiation will pass on through while some will be absorbed or scattered. As the thickness of the absorber is increased, the fraction of the radiation passing through will decrease. When exactly half the radiation passes through the absorber (the other half being absorbed or scattered, the thickness of the absorber is called the half-value layer, HVL, or the half thickness, $X_{\frac{1}{2}}$.

Since the intensity of radiation is reduced by 50% by passing through one HVL, it will be reduced by another 50%, or to only 25% of the original intensity, in passing through a second HVL of absorber. This is illustrated in Figure C-6 A linear relationship is obtained if the data are plotted using semilog paper or if the logarithm of the activity is plotted as a function of the absorber thickness. See Figure C-7.

APPARATUS

G-M tube and scaler or, preferably, a scintillation detector and scaler; timer; absorber set.

MATERIALS

Gamma source.

PROCEDURE

Take a background count and record. Place the gamma source in the sample holder and insert in the second or third shelf of the tube stand. Place the empty absorber slide in the shelf immediately above the sample.* In this way, determine the activity of the sample with no absorber. Record all data.

Now insert the thinnest absorber in the absorber slide and determine the sample activity again. Record Repeat with the other absorbers, going from the thinnest to the thickest. Record all data.

DATA

Absorber Thickness mg/cm^2	Activity cpm	Corrected Activity cpm
none		

CALCULATIONS

The activities must be corrected for background and resolving time. After this has been done, plot a graph of the results on semilog paper with the corrected activity on the y-axis against absorber thickness on the x-axis. Determine the HVL graphically.

Compare your gamma-absorption graph with the beta-absorption graph obtained in experiment 38. Are they similar or dissimilar?

QUESTIONS

1. Account for the difference, if any, between gamma and beta absorption.
2. What are some ways in which gamma rays react with matter?
3. What type of shielding would you recommend for protecting against gamma rays?

*If a beta-gamma source is used, a 3/8" thick plastic, absorber must be used between the source and absorbers to filter out the betas.

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