Further Measurements on the Disintegration Curve of Mesotrons

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Abstract

Further measurements have been made on the disintegration curve of mesotrons. An extensive set of data gives a mean lifetime of 2.15 ± 0.07 microseconds as calculated from the differential disintegration curve.

1 Experimental Procedure

The authors of the present paper have recently described a method for the experimental determination of the disintegration curve of mesotrons and have given a preliminary account of the results obtained.[1] The method has been since improved and a new and more extensive set of data has been taken. A summary of the new results is presented here.

The experimental arrangement, which is similar in principle to that used in the previous experiment, is schematically represented in Fig. 1. The three counters L are in parallel, and so are the four counters B and the five counters M. Counters A_1, A_2, and B feed into the "time circuit" T; this circuit gives a pulse whose amplitude is a function of the time delay between a coincidence A_1A_2 and the subsequent pulse of B. Counters L, A_1, A_2, B, and M feed into an anticoincidence circuit C, which records the anticoincidences $LA_1A_2B - M$, i.e., the coincidences between LA_1A_2 and B which are not accompanied by a pulse in M. The recording circuit R operates a pen writing instrument in such a way that the pulse from the time circuit is recorded only when it is accompanied by a pulse from the anticoincidence circuit.

[1] B. Rossi and N. Nereson, Phys. Rev. **62,** 417 (1942).

The events which one desires to record are of the following type. A mesotron traverses the counters L, A_1, and A_2, is stopped in the absorber A, and then disintegrates giving rise to an electron which discharges one of counters B. The amplitude of the pulse from the time circuit, as recorded by the pen writing instrument, gives a measure of the life span of the mesotron in the absorber.

In addition to the records representing disintegration events, records will be obtained whenever showers or other spurious effects discharge L, A_1, A_2, B, and fail to discharge M. In these cases counters A_1, A_2, and B are discharged almost exactly at the same time. However, small delays may be recorded because of the spontaneous time lags of counters. Previous experiments have shown that the time lags of counters hardly ever exceed 0.8 μsec. Thus, no spurious delays due to time lags of counters will be recorded if all delays less than 0.8 μsec. are disregarded in the data.

As discussed in the paper previously quoted[1] errors may arise on account of "chance coincidences" between two spurious events, between a spurious event and a real disintegration event, or between two real disintegration events. The number of these coincidences has been greatly reduced in the present experiment as compared with the previous one through a more careful design of the circuits. Actually, if we confine ourselves to delays larger than 0.8 μsec., we can say that out of every 1000 events recorded as disintegrations, only six on the average are due to chance coincidences, while ten of the records are slightly modified by overlapping between true and spurious events, and six disintegrations may be expected to be missed on account of overlapping between disintegration events. These numbers are very small and thus the errors caused by chance coincidences can be disregarded.

2 Experimental Results

The combined measurements represent about 4000 hours of observation distributed over a period of seven months during which a total of approximately 3000 decay electrons emitted with a delay larger than 0.8 μsec. were recorded. During the measurements the time circuit was calibrated twice a week with artificial pulses whose time separation was determined by a quartz oscillator.[1] The deviations between consecutive calibrations never exceeded 0.1 μsec., while the maximum variation of the calibration curve at any one point during the entire seven-month period was 0.2 μsec.

Measurements were taken with absorbers of lead (1303 hours), brass (937 hours), and aluminum (452 hours) in A. In all cases the size of the absorber

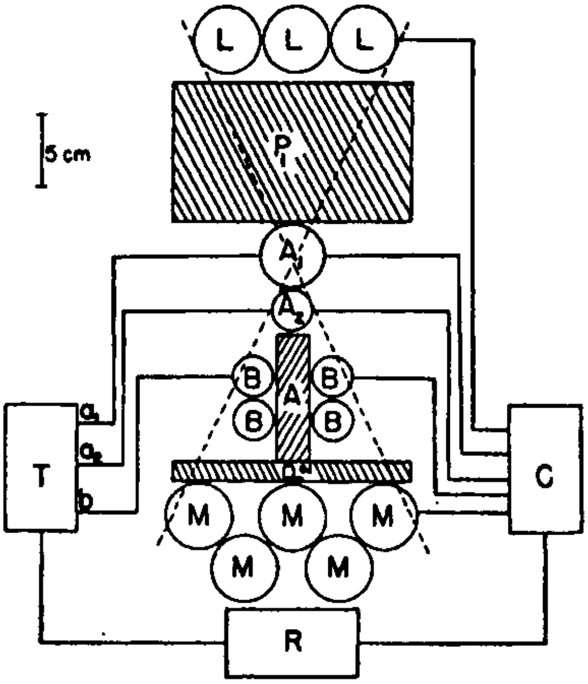

Figure 1: Experimental arrangement used in the determination of the disintegration curve of mesotrons.

was 25.5 $\times$ b $\times$ 2.3 cm. Measurements were also taken with no absorber (1302 hours). The results are presented in the form of integral disintegration curves in Fig. 2. Actually, all delays up to 15 μsec. (the resolving time of the anticoincidence circuit) were recorded in the experiment but the points corresponding to delays above 10 μsec. have rather large statistical errors and are not presented here. In these graphs the ordinates give on a logarithmic scale the number of mesotrons whose life span τ in the absorber is larger than the corresponding abscissa. Except for the points below 0.8 μsec., the experimental points for the three absorbers fall on practically straight lines which all show about the same slope. This indicates that mesotrons decay exponentially and that the average lifetime is the same in the different absorbers as, of course, one would expect. The deviations of the points obtained with the aluminum absorber from a straight line are larger than those for the lead or brass absorbers since fewer disintegration events were observed for aluminum. The measurements with no absorber are also subject to rather large statistical fluctuations. However, the corresponding

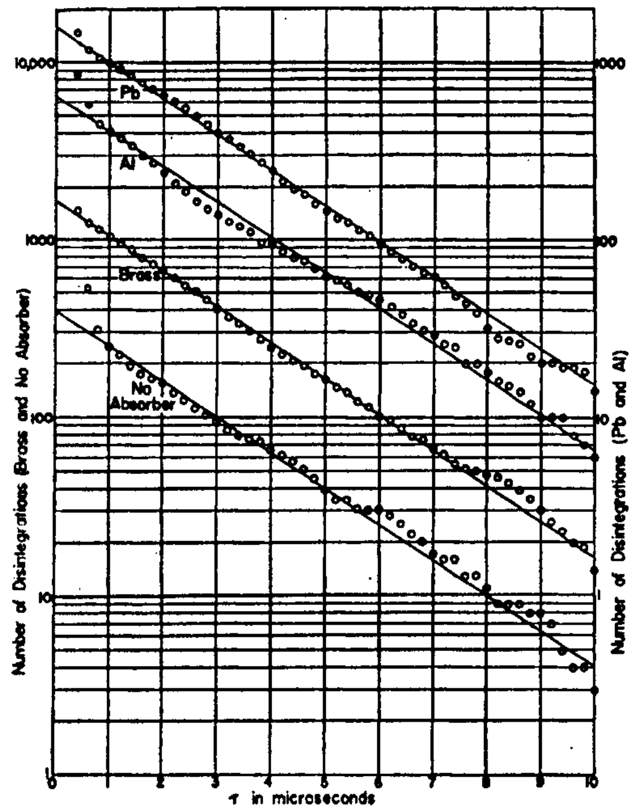

Figure 2: Integral disintegration curves of mesotrons obtained with lead, aluminum, brass, and no absorber in A.

curve is again approximately a straight line parallel to the other three, indicating that most of the events recorded with no absorber are disintegrations of mesotrons stopped in the walls of the counters or in the permanent lead absorber P_2.

The results obtained with lead, brass, and aluminum are combined into a single differential disintegration curve in Fig. 3 (lower curve). In this figure the number of mesotrons whose life is between τ and $\tau + \Delta\tau$ is plotted on a logarithmic scale against $\tau + \Delta\tau/2$, where $\Delta\tau$ is chosen as 0.4 μsec. A straight line has been fitted to the experimental points corresponding to delays larger than 1 μsec. by the method of least squares. The equation of

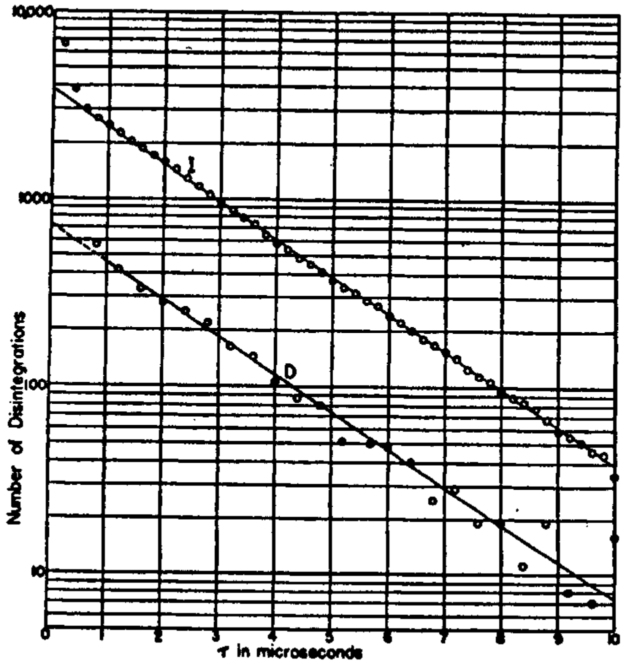

Figure 3: Differential (D) and integral (I) disintegration curves of mesotrons obtained from the combined data of the lead, brass, and aluminum absorbers. The straight line through the experimental points for the differential curve is drawn according to the method of least squares.

this line gives for the mean lifetime of mesotrons the following value:

$$\tau_0 = 2.15 \pm 0.07\ \mu\text{sec.},$$

where the error indicated represents the standard statistical error. The same value is obtained when only experimental points lying in the regions from 1 to 8 and 1 to 6 μsec. are used to determine the equation of this line. The corresponding combined integral curve is also plotted in Fig. 3; a straight line having a slope corresponding to the above lifetime is drawn through the experimental points.

The previous measurements[1] gave $\tau_0 = 2.3 \pm 0.2\ \mu$sec. The difference between the two values of τ_0 is well within the statistical error. The new value, of course, is much more accurate.

Straight lines with slopes corresponding to $\tau_0 = 2.15\ \mu$sec. are also drawn through the experimental points in Fig. 2. The intersections with the ordinate axis gives the total numbers of disintegration electrons recorded. These numbers divided by the total time of observation are listed under n in Table I. The difference $n - n_0$ between the values of n with a given absorber and with no absorber represents the number of decay electrons per hour coming out of the absorber and recorded by counters B.

Table I also lists under N the number of anticoincidences $LA_1A_2 - M$ per hour recorded with each of the three absorbers and with no absorber. By subtracting the anticoincidences recorded with no absorber, N_0, from the anticoincidences recorded with a given absorber, N, one obtains the average number of mesotrons stopped per hour by the particular absorber

TABLE I. Summary of the experimental results. N is the number of anticoincidences $LA_1A_2 - M$ per hour, and n is the number of disintegration electrons recorded per hour (extrapolated value).

	N	$N - N_0$	n	$n - n_0$	$\frac{n-n_0}{N-N_0}$
Lead	40±2	17±2	1.20±0.03	0.90±0.04	0.05±0.01
Brass	40±2	17±2	1.76±0.04	1.46±0.05	0.09±0.01
Aluminium	29±1	6±1	1.43±0.06	1.13±0.06	0.19±0.03
No absorber	23±1	–	0.30±0.02	–	–

(second column). The last column of Table I gives the "yield," namely, the ratio $(n - n_0)/(N - N_0)$ between the number of decay electrons recorded and the total number of mesotrons stopped.

The ratios between the numbers $N - N_0$ of the mesotrons stopped in the three absorbers correspond very closely to the theoretical predictions, based upon the theory of ionization losses of mesotrons in matter (see especially the paper by Rossi and Greisen[2]). The yield $(n - n_0)/(N - N_0)$ appears to be a rapidly decreasing function of the atomic number. This is exactly what one would expect because the range of the disintegration electrons decreases rapidly as the atomic number is increased.

In aluminum the average range of the disintegration electrons, which have an energy of about 40 Mev, is approximately 6 cm. Since the thickness of the absorber is 2.3 cm, it may be assumed that almost all of the disintegration electrons produced in the aluminum come out of the absorber. If all mesotrons stopped in the absorber disintegrated, the average "yield" in the case of aluminum should be approximately equal to $1/4\pi$ times the average solid angle subtended by counters B from the point where the disintegration

[2]B. Rossi and K. Greiaen, Rev. Mod. Phys. **13,** 240 (1941).

occurred. From a rough evaluation of this solid angle, one estimates a yield of about 0.5 while the experimental value of $(n - n_0)/(N - N_0)$ is about 0.2. This would seem to indicate that only half of the absorbed mesotrons undergo disintegration, in agreement with the results of Rasetti.[3]

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[3]F. Rasetti, Phys. Rev. **60,** 198 (1941).