tions were made for back-scattering, absorption in the air gap, and counter window.

The value we obtained was 7200±500 years.

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[2] L. D. Norris and M. G. Inghram, Phys. Rev. 73, 350 (1948).
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The Absorption of Charged Particles from the 2.2-μsec. Meson Decay

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THE energy spectrum of the charged particles (commonly assumed to be electrons) emitted in the 2.2-μsec. meson decay is still unknown. Conversi and Piccioni[1] in 1944 deduced from the relative numbers of decay electrons escaping from iron plates 0.6 cm and 5 cm thick that their mean range is about 2.5 cm of iron. According to the range-energy relationships of Bethe-Bloch-Heitler,[2] this corresponds to an energy of about 50 Mev, which was consistent with the Yukawa β-process picture of a meson decaying into an electron and a neutrino, each of about 50 Mev. Subsequently, Anderson and co-workers[3] observed two instances of meson decay in a cloud chamber, and were able to measure accurately the energy of the decay electron. This was found in both cases to be close to 25 Mev. To explain this low energy they postulated that the decay process might be

$$\text{charged meson} \rightarrow \text{electron} + \text{neutral meson}, \qquad (1)$$

with the kinetic energy of the electron having a unique value of about 25 Mev. Since the present experiment was initiated there have been reported a few results[4] obtained with cloud chambers that seem to indicate a considerable spread in the energies of the decay particles. A 3-particle decay process in which the electrons may be emitted with any energy up to about 50 Mev has been suggested recently.[5]

Our experiment, carried out in the Chalk River Laboratory, is an attempt to derive some information about the energy of the decay electrons by measuring their penetration through a solid absorber. The method differs from that used by Conversi and Piccioni; in particular, a low atomic number absorbing material (carbon*) for the electrons was used in order to decrease the energy losses by radiation which complicate the interpretation of the experiment.

A section of the counter arrangement, together with a block diagram illustrating the function of the electronic circuits, is shown in Fig. 1. A meson beam entering the apparatus is defined by a coincidence between counter trays A and B. The positive and negative mesons which are stopped in a graphite block 20 cm×40 cm×4.2 g/cm² thick are detected by the anticoincidence $(AB-C)$, which initiates a grating pulse 4.6 μsec. in width and delayed by ~1 μsec. This pulse is then mixed separately with the outputs from A, B, and C, so that if the decay electron passes through A, B, or C between 1 and 5.6 μsec. after an anticoincidence $(AB-C)$, a delayed coincidence is recorded which we designate by $(A)_{\text{del}}$, $(B)_{\text{del}}$, or $(C)_{\text{del}}$. In particular, a decay electron passing through both B and A gives an event $(AB)_{\text{del}}$.

In order to measure the penetration of the decay electrons, the rate $(AB)_{\text{del}}$ is measured as a function of the thickness of a graphite absorber placed between A and B.** Some events $(AB)_{\text{del}}$ are also events $(ABC)_{\text{del}}$ and are caused essentially by a meson traversing the three trays by chance within the delayed interval. The events $(ABC)_{\text{del}}$ are also recorded and enable us to disregard most of the chance $(AB)_{\text{del}}$.

It will be noticed that A and B have two functions: (i) detecting the passage of the primary meson and (ii) detecting the passage of a decay electron. Because of the counter dead time, only those decay electrons will be detected which pass through a different counter from that traversed by the meson. This decrease in the effective sensitivity of tray B would be serious if the meson absorber (i.e., the "source" of decay electrons) were placed very close to B; a favorable position of the source (4.1 cm below B) was determined graphically.

The results are summarized in Table I.

The interpretation of an electron absorption curve is made difficult by the inherent presence of scattering and radiation, and, in our experiment in particular, by the low intensity and "poor geometry." Nevertheless, the following conclusions can be drawn.

Let us assume first that the energy of the decay electrons is always 25 Mev. The *maximum* range of a 25-Mev electron (defined as $\int_0^{25\text{ Mev}} dE/-(dE/dx)_{\text{ion}}$, where $-(dE/dx)_{\text{ion}}$ is the rate of energy loss in Mev×cm²/g due only to non-radiative collisions), is estimated[2,6] to be 15 g/cm² in carbon. Now we have calculated (cf. reference

TABLE I.

Absorber thickness	Total thickness* (g/cm²)	Hours of observation	$(B)_{\text{del}}$ (counts)	$(C)_{\text{del}}$ (counts)	$(AB)_{\text{del}}$ (counts)	$(ABC)_{\text{del}}$ (counts)	$(B)_{\text{del}}+(C)_{\text{del}}$ (cts./hr.)	$(AB)_{\text{del}}-(ABC)_{\text{del}}$ (cts./hr.)
No absorber	4.2	212	840	1856	176	6	12.7±0.3	0.80±0.06
5.1 g/cm² C	9.3	67	246	588	38	2	12.4±0.4	0.54±0.09
13.7 g/cm² C	17.9	142	695	1301	30	6	14.1±0.3	0.17±0.04
16.2 g/cm² C	20.4	250	1009	2073	31	6	12.3±0.3	0.10±0.02
16.2 g/cm² C+2.7 g/cm² Fe	23.1	158	683	1373	12	3	13.0±0.3	0.06±0.02
96.5 g/cm² Pb+5.8 g/cm² Fe (control run)	106.5	158	637	1494	2	2	13.5±0.3	0 in 158 hr.**

* To the absorber thickness has been added the thickness of counter walls (2.1 g/cm² Cu) and half the thickness of the graphite source (2.1 g/cm² C).
** The computed casual rate is about 0.003/hr.

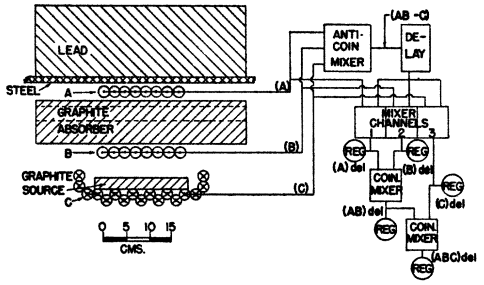

FIG. 1. Experimental arrangement. The geometry in the plane perpendicular to the paper can be inferred from the length of the counters, which is 35 cm.

2) that less than 0.03 count per hour can be due to radiation from 25-Mev electrons in our arrangement. Consequently, it may be seen from Table I that at least a substantial fraction of the electrons must have a range greater than 15 g/cm² of carbon. Therefore, we conclude that there are decay electrons having energies greater than 25 Mev and therefore that the 2-particle decay process (Eq. (1)), with a *unique* energy of about 25 Mev for the decay electron, is incompatible with our results.

We observe, however, that a *maximum* energy of about 50 Mev for the decay electrons would be consistent with the data of Table I.

* For one run a small thickness of iron was added on top of the graphite.

** The absorber for the decay particles, when placed between A and B, produces a negligible change in the number of mesons stopped in the graphite below B, so that the strength of the "source" of decay electrons is sensibly constant as indicated by the rate $(B)_{del}+(C)_{del}$.

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The Self-Diffusion Coefficient of Nitrogen*

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AN approximation to the self-diffusion coefficient of nitrogen at room temperature has been determined, using a method originated by Ney and Armistead and previously applied to uranium hexafluoride[1] and methane.[2] This consisted of allowing nitrogen having 7.4-atom percent enrichment of N^{15}, supplied by the Eastman Kodak Company, to diffuse into normal nitrogen at the same temperature and pressure. Because of the chemical similarity and the small mass difference between the molecules $N^{14}N^{14}$ and $N^{14}N^{15}$, the coefficient of diffusion of the one into the other should be very nearly the same as the coefficient of self-diffusion of either.

The apparatus used consisted of two cylindrical copper bulbs, having volumes of 924 cm³ and 249 cm³, mounted on a common axis and connected through a copper tube and brass ground-joint stopcock, the tube and stopcock assembly having a uniform bore of 0.635 cm and an over-all length of 16.23 cm. In performing the diffusions heavy nitrogen was placed in one bulb and the normal gas in the other at the same temperature and pressure. After opening the connecting stopcock a continuous analysis of the concentration of $N^{14}N^{15}$ in the small bulb was performed with a 60° Nier-type mass spectrometer, the rate at which this concentration changed providing a means of evaluating the coefficient of diffusion. In order to obtain a relaxation time of about an hour and a half all diffusions were performed at room temperature and at pressures of from five to six cm of mercury.

In the kinetic theory of transport phenomena there is derived the relation $\rho D=\epsilon\eta$, where ρ is the density, D the coefficient of self-diffusion, η the coefficient of viscosity, and ϵ a constant related to the intermolecular forces. Taking ρ for nitrogen to be 1.2506×10^{-3} g/cm³ at 0°C and 760 mm of mercury pressure, and assuming the ideal gas law to hold, the mean of five diffusions referred to 20°C is: $(\rho D)_{20°C}=258\pm10$ micropoises. The precision measure assigned is the most probable cumulative error arising from errors in the measurement of the geometrical constants, pressure, and temperature, as well as instrument error.

Taking η at 20°C to be 174.7 micropoises,[3] it is found that $\epsilon=1.48$. If the nitrogen molecules be represented as point centers of repulsive force, Chapman and Cowling[4] compute that $\epsilon=1.44$, using the experimentally verified relation $\eta\propto T^{0.756}$. This theoretically determined figure agrees with the observed value within the limits of experimental error. This agreement between experiment and theory is of especial interest, since the values reported for ϵ for uranium hexafluoride,[1] methane,[2] and argon[5] show a departure from the simple theory and yet agree with each other within the limits of error. This unexpected result led at first to the suspicion that ϵ might have the same value for all gases, but the figure reported here does not support such a belief.

Experimentally determined values of ϵ for various gases are listed in Table I, which, with the addition of the result for nitrogen, is reproduced from a paper by Hutchinson[5] and illustrates the as yet unexplained behavior of this quantity.

Amdur[6] has already pointed out that the molecular model assumed by Chapman and Cowling may be incomplete, it being more appropriate to represent the interactions as a sum of both repulsive and attractive forces.

TABLE I. Reported values of ϵ.

Gas	Temperature, °C	ϵ
H_2	20	$1.37_0\pm0.003$
	−188	1.32 ±0.06
	−252.8	1.28 ±0.02
Ne	20	$1.27_8\pm0.006$
A	22	1.31 ±0.01
Kr	20	1.30 ±0.06
Xe	20	1.24 ±0.06
CH_4	20	1.33
UF_6	30	1.31
N_2	20	1.48