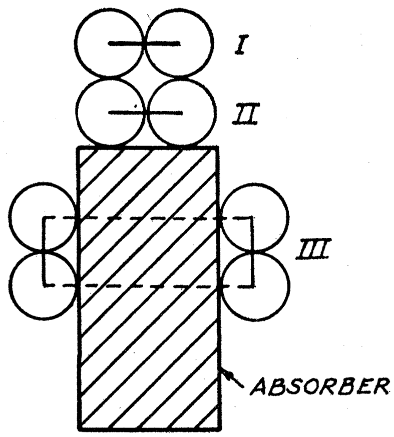

FIG. 1. Experimental arrangement.

The experimental arrangement is shown in Fig. 1. The moderator is 2″×4″×14″. The G-M counters for detecting the mesons and the decay electrons all have 1″ diameter and 12″ sensitive length. The mesons entering the absorber are observed as a double coincidence in counter trays I and II. The decay electrons coming out from the absorber are detected in counter tray III containing four counters.

Absorbers of the following materials have been used: Be, C, NaOH, Al, SiC, and S. The decay curves for the different absorbers are still rather inaccurate and do not show any definite disagreement with a mean life of 2.2 μsec.

To compare the number of decay electrons from the different absorbers, we count the number of impulses from counter tray III that are delayed between 1 and 6 μsec. with respect to the coincidences I×II. The most reliable results come from a comparison of beryllium and sulphur absorbers of equal stopping power. The same number of mesons will be stopped in both, and in both cases the same fraction of the decay electrons will be stopped in the absorber before reaching the counters. We have counted the delay pulses with and without absorber, changing absorber every day. An 8-day long run gives the result of Table I.

Similar runs have been made for other absorbers. The results are given in Table II. To get the ratios for the number of emitted decay-electrons the figures of Table II have to be corrected for the absorption of the decay-electrons. The detailed evaluation of this effect has not yet been completed, but the ratio will have to be reduced by an amount estimated to be roughly of the order of 20 percent for C and 10 percent for NaOH and SiC.

TABLE I.

Absorber	Be	S	None
Mass	3290 g	3440 g	
Relative stopping power per g/cm³	1.05	(1.00)	
Relative number of mesons calculated to be stopped	1.00	(1.00)	
Delayed counts	219	213	29
Time of observation	58 hr.	84.3 hr.	44 hr.
Counts per hour corrected for background	3.12±0.18	1.87±0.10	
Relative number of disintegrations for equal number of mesons stopped	1.67±0.14		
Ratio of total number of mesons at sea level to number of positively charged mesons[a]	1.8		

[a] D. J. Hughes, Phys. Rev. 57, 592 (1940).

TABLE II.

Absorber	Al	C	NaOH	SiC
Mass	4680 g	2730 g	3440 g	3780 g
Counts, corrected for background, and reduced to equal numbers of mesons stopped	(1.00)	1.7±0.2	1.4±0.1	1.0±0.1

The present results confirm the findings of Conversi, Pancini, and Piccioni,[1] that negative mesons absorbed in carbon emit decay-electrons whereas no decay-electrons are observed if they are absorbed in iron. The absence of decay-electrons is easily explained by assuming that the negative mesons are captured by the nucleus.[2]

Our results indicate that the capture probability (*a*) increases gradually with increasing atomic number, but (*b*) disagrees completely in absolute value with the predictions[2] of the meson theory of nuclear forces.

This work has been supported by Navy Bureau of Ordnance Contract 7920 with Princeton University. We are indebted to the Radio Corporation of America, Princeton Laboratories, for development of a special time measuring and recording device used in these experiments, which are continuing and will be further reported.

[1] M. Conversi, E. Pancini, and O. Piccioni, Phys. Rev. 71, 209 (1947).
[2] S. Tomonaga and G. Araki, Phys. Rev. 58, 90 (1940).

Mechanism of Capture of Slow Mesons[1]

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THE Rome group[2] observe that negative mesons stopped in carbon undergo radioactive decay but that those stopped in iron do not. The measurements of Sigurgeirsson and Yamakawa[3] indicate (1) that for other light elements the probability of nuclear capture is likewise small, relative to the probability of radioactive decay ($1/\tau_0=1/2.15\times10^{-6}$ sec.); and (2) that the ratio of the two transition probabilities rises with atomic number, passing through the value unity for an atomic number, Z_0, probably in the neighborhood of $Z_0\sim10$.

It follows from these observations that the time required for nuclear capture in light elements is 10^{-6} sec. or more, far longer than the time taken by the meson to reach its lowest Bohr orbit about the nucleus *via* radiation and Auger effect.[4] Consequently it is only for a negative meson *moving in a K-orbit* of a nucleus of charge Z_0 that nuclear capture and normal radioactive decay must be considered to have the same probability. For mesons in higher orbits or in the free state direct capture by the nucleus must be concluded to have negligible probability ($\sigma = 2\times 10^{-32}$ cm^2 ev/(energy of meson)).

In the K-orbit of another nucleus of charge Z the probability of nuclear capture may be expected to be greater (a) by the factor (Z/Z_0) for the larger number of protons presumably capable of being transformed into neutrons and (b) by the volume concentration factor $(Z/Z_0)^3$ based on the expression $(\hbar^2/\mu Z e^2)$ for the effective radius of the Bohr orbit. Combination of factors gives for the expected decay constant for negative mesons stopped in matter, $1/\tau = (1/\tau_0)[1+(Z/Z_0)^s]$, and for the fraction which send out decay electrons the expression,

$$f = [1+(Z/Z_0)^s]^{-1}.$$

An appreciable dependence of the mechanism of dissipation of energy upon atomic number will be expected to alter the value of the exponent, $s=4$, deduced above.

A significant fraction of the moderated negative mesons will arrive at the $2s$ orbit and might be expected to remain in a metastable state with a decay probability lower than that calculated above. However, the finite extension of the nuclear charge inverts the normal order of $2s$ and $2p$ terms (by $\sim$3000 ev in Al) and gives the $2s$ state a short life with respect to radiation ($\sim 2\times 10^{-9}$ sec. for Al). Also direct transitions from $2s$ to $1s$ may occur *via* transfer of energy to a $1s$ electron (4×10^{-10} sec. in Al). Consequently only nuclear capture from the K-orbit need be considered.

The Auger electrons given out in $2s \rightarrow 1s$ and $2p \rightarrow 1s$ transitions (0.7 Mev in argon, 1.4 Mev in iron) offer an independent means to determine the mass of the meson. For nuclei of charge $Z>23$ pair production is also possible in the $2s \rightarrow 1s$ transition but has negligible probability.

For a nucleus provided with 100 Mev of excitation by meson absorption, evaporation of 6–15 nucleons (nuclear "star") will be expected to have a probability $\sim 10^6$ times greater than the probability of electromagnetic radiation. Stars at mountain altitudes are too frequent for all to be accounted for by meson absorption. Whether conversely all negative mesons stopped at sea level ($\sim$400 observed per m^3 of air per day) can be assumed to produce stars ($\sim$300/m^3 day as deduced from photographic plates) appears an open question in view of existing experimental uncertainties. Neither experimentally nor theoretically can one exclude the possibility of some other process for dissipation of the mass energy of the meson.

Straightforward application of the law of microscopic reversibility gives $10^{-40}(Z/Z_0)^{s-2}$ cm^2 as upper limit for the (γ, μ) reaction produced by γ-rays in the 100-Mev range, and a correspondingly low probability for production of mesons by heavy particle bombardment.

A more detailed article is being prepared.

[1] See also J. A. Wheeler, same title, Bull. Am. Phys. Soc. **22**, No. 1, Abstract No. A4 (1947).
[2] M. Conversi, E. Pancini, and O. Piccioni, Phys. Rev. **71**, 209 (1947). The author is indebted to Dr. Piccioni for preliminary communication of these results.
[3] T. Sigurgeirsson and A. Yamakawa, preceding letter.
[4] E. Fermi, E. Teller, and V. Weisskopf, this issue, give an explicit formula for the rate of loss of energy by Auger transitions between orbits of large quantum number. The author is indebted to these authors for the opportunity to see their letter before publication.

Gamma- and Beta-Ray Energies of Some Radioactive Isotopes as Measured by a Thin Magnetic Lens Beta-Ray Spectrometer*

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A THIN magnetic lens beta-ray spectrometer, similar to that developed by Deutsch[1] and his co-workers, was constructed by the authors for the purpose of measuring radioactive isotopes produced at the Clinton pile. The instrument was designed primarily for the study of beta-radiations between the energies of 0.1 to 3.0 Mev. The momentum of the focused electrons is determined by the relation $P=kI$, where I is the current through the lens coil and k is a constant depending on the geometry of the coil. Since the electron paths are quite complicated, no attempt is made to use the spectrometer as an absolute instrument; i.e., k is determined experimentally. To determine k, the F conversion line of thorium B ($H\rho = 1385$) and the photoelectron line due to annihilation radiation from positron emitters (0.511 Mev) are used. Agreement between the two calibrations is obtained to about 0.1 percent. Half-intensity widths between 2 and 4 percent are obtained for conversion lines, and between 4 and 6 percent for photoelectron lines. Beta- and gamma-sources as weak as 0.005 and 0.1 mc, respectively, have been successfully used.

Table I lists the results of most of the investigations. The values given for the gamma-ray energies are accurate to about 2 percent. The estimates of the relative intensities of the gamma-rays are only approximate and the values for the smaller components should be taken as indications only.

TABLE I.

Element	Half-life	Max. beta-ray energy (Mev)	Gamma-ray energy (Mev)	Relative intensity
*Sr^{89}	55*d*	1.5±.1		
*Cb^{95}	37*d*		†.75	
Ag	225*d*	0.59±.05	†.66	44
			.90	47
			1.40	9
Sb^{122}	2.8*d*		†.57	
Sb^{124}	60*d*		1.72	
$Te^{122,124?}$	30*d*?		.61	
*Te^{129}	1.2*h*	1.8 ±.1		
*Ba^{140}	12.5*d*	1.05+.05	†.54	
*La^{140}	40*h*	1.45±.1	.335	2
			.49	5
			.87	10
			1.65	77
			2.3	6
Ta^{182}	120*d*	0.53±.03	†.15	2
			.22	4
			1.13	37
			1.22	57
Pb^{209}	3.3*h*	0.68±.03		

* Fission product.
† Internal conversion of the gamma-ray noted.

* This document is based on work performed for the Manhattan Project, and the information covered therein will appear in Division IV of the Manhattan Project Technical Series as a part of the contribution of the Clinton Laboratories.
[1] Deutsch, Elliot, and Evans, Rev. Sci. Inst. **15**, 178 (1944).