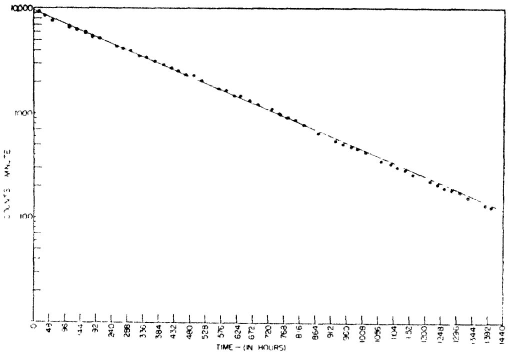

FIG. 1. Decay curve Cs^{131}.

using cesium and barium carriers. The cesium was then separated as the perchlorate and exhaustively purified.

The half-life was measured over a period of six half-lives and found to be 9.6±0.1 days by the method of least squares. The decay curve is shown in Fig. 1. We find, in great abundance, a soft radiation which may be ascribed to the conversion electrons found by Kurbatov *et al.* An absorption curve in aluminum is shown in Fig. 2. This consists of two components, the softer of which is replotted on a larger scale. Assuming that the softer radiation may be treated as though it were similar to a continuous spectrum of β^--radiation, the energy has been determined by back-scattering[4] and found to be 115 kev. The harder component has a half-thickness of 700 mg/cm² and is identical with the 31-kev x-ray found by Katcoff.

If P = the number Ba^{130} atoms irradiated, Q = the number Ba^{131} atoms formed, R = the number Cs^{131} atoms formed, σ = the cross section of Ba^{130} for capture, ρv = neutron flux, t = duration of irradiation, and λ and λ' are the disintegration constants for Ba^{131} and Cs^{131}, respectively, then

$$\sigma=\frac{R}{\rho vP[[(1-e^{-\lambda' t})/\lambda']-[(e^{-\lambda t}-e^{-\lambda' t})/(\lambda'-\lambda)]]}.$$

The Cs^{131} activity obtained was corrected for decay elapsing between removal of the sample from the pile and chemical separation, time elapsing between chemical separation and measurement, chemical recovery, counter efficiency, absorption in sample, in counter window and in air gap between counter window and sample, and back-scattering from tray. The flux was experimentally determined using La^{139}. Its cross section has been taken to be 8.4 barns.[5]

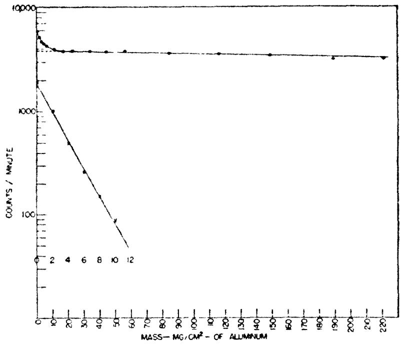

FIG. 2. Cs^{131} absorption curve using aluminum.

Assuming that the Cs^{131} γ-ray is 97 percent converted, the cross section for neutron capture of Ba^{130} has been found to be 24±8 millibarns.

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Table of Interplanar Spacings for Different Target Materials for the Back Reflection Region

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January 3, 1949

A TABLE has been computed to expedite the reduction of diffraction patterns obtained in the back reflection region and may be considered a continuation of Research Report R-94602-10-C.

The table gives d values for Mo, Cu, Co, Fe, and Cr targets for every tenth of a degree in 2θ, or five hundredths of θ, to four and five significant figures. The values of the interplanar spacings, d, are computed from the Bragg equation: $n\lambda=2d\sin\theta$ where θ is the glancing angle, λ the wave-length of the diffracted target radiation, and n is taken as unity. The table is computed in angstrom units for the $K\alpha_1$ radiation and factors are given for converting these spacings to those for $K\alpha_2$ and $K\alpha$. Conversion curves from $K\alpha_1$ to kx units are also given for all five target materials over the angular range.

The tables may be obtained directly from the author.

On Mesons π and μ

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December 23, 1948

SEVERAL papers have recently appeared[1-3] which raise certain doubts about the two-meson hypothesis proposed by the author[4] in order to explain the contradictory behavior of high altitude and sea-level mesons. It seems worth while to clarify the fundamental ideas of the two-meson theory and to discuss briefly its status in the light of the latest experimental results.

The two-meson hypothesis stated: (1) the mesons produced with large cross section at high altitudes are different from the majority of weakly interacting sea-level mesons, (2) the high altitude mesons are strongly coupled to nucleons, whereas the sea-level mesons are the decay products of the high altitude mesons, (3) a weak coupling of sea-level mesons to nucleons follows from (2). It was not possible to make unique assignments for the spins and masses of the two types of mesons.

The striking experimental discoveries of Powell and his collaborators[5] and the Berkeley group[6] have provided complete confirmation of points (1) and (2). Thus, it is now established that the π-mesons are produced directly in the Berkeley cyclotron and in cosmic-ray stars while the μ-mesons arise indirectly from the decay of the π-mesons. It is furthermore established that π^--mesons are captured by light as well as heavy nuclei in contrast to the μ^--mesons which are only captured by heavy nuclei. These results are contrary to the cloud-chamber evidence[1] for the direct production of μ-mesons and it is likely that visual methods for estimating ionization are not sufficiently accurate to distinguish between π- and μ-mesons.

Definite support for point (3) is provided by the measured value of the half-life for the π–μ-decay, i.e. $0.9^{+0.25}_{-0.15}\cdot 10^{-8}$ sec.,[7] and the fact that nuclear capture of π^- converts an appreciable fraction of its rest energy into star energy,[5] whereas nuclear capture of μ^- converts a negligible fraction of its rest mass into star energy.[8] Both of these facts can be understood on the basis of (3) and assuming that the π-meson is a boson; thus, the scheme for the nuclear capture of μ^- becomes: $\mu^- + P \rightarrow \pi^- + Q + P \rightarrow N + Q$ where P and N are the proton and neutron in the nucleus and Q is the second particle into which the π-meson decays, i.e. $\pi \rightarrow \mu + Q$. The predicted half-life[2, 9] for the π–μ-decay agrees well with the measured value considering the uncertainty of the nuclear matrix element. Our original calculation[4] for the half-life treated the π-meson as a fermion for the purposes of illustration; the value of 10^{-8} sec. obtained demonstrates the insensitivity of the half-life to the spin character of the π-meson.

An alternative interpretation of the half-life for π–μ-decay and of the qualitative features of the nuclear capture of negative π- and μ-mesons has been suggested:[3, 9] One postulates a direct (weak) coupling between the μ-meson and nucleon and a direct (strong) coupling between the π-meson and nucleon and one *deduces* the π–μ-decay. This is a possible approach but against it two objections may be raised: (1) the calculation of the indirect decay of the π-meson through the virtual creation of nucleons leads to divergence difficulties and (2) the rough quantitative agreement found between the coupling constant for the μ-meson and the nucleon and the β-constant may not be significant in view of the uncertain status of β-decay theory.[10]

Additional experiments have fixed some of the other unknowns in the two-meson theory. The determination[7] of the ratio of masses of the π- and μ-mesons as 1.321 ± 0.006 and the absence of γ-rays[11] associated with the nuclear capture of μ^- prove that the particle Q is a neutrino. Consequently, the μ-meson is a fermion and must possess[12] spin $\frac{1}{2}$. This value of the spin is consistent with the apparently continuous electron spectrum from the μ-decay. The spin of the π-meson is still uncertain.

Major difficulties remain: the possibility of correlating nuclear β-decay with an electron decay of the π-meson appears to be excluded,[6] and it is not at all clear that a correct field theory of nuclear forces can be constructed with only one strongly coupled meson.[4]

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[7] R. Serber, private communication.

[8] See also Sard, Ittner, Conforto, and Crouch, Phys. Rev. **74**, 97 (1948).

[9] A. S. Lodge, Nature **161**, 809 (1948), L. I. Schiff, Phys. Rev. **74**, 1556 (1948), R. F. Christy, private communication.

[10] R. E. Marshak, Phys. Rev. **75**, 513 (1949).

[11] O. Piccioni, Phys. Rev. **74**, 1236 (1948).

[12] R. F. Christy and S. Kusaka, Phys. Rev. **59**, 414 (1941).

Erratum: Thermonuclear Reactions in the Expanding Universe

[Phys. Rev. **74**, 1198 (1948)]

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It is regretted that Eq. (3) was incorrectly given; it should read:

$$d[\ln x_2]/dt = -pm_2/x_2. \tag{3}$$

Measurement of the Half-Life and Average Energy of Tritium Decay*

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December 29, 1948

Recently, Novick[1] and Goldblatt *et al.*[2] have found the half-life period of tritium to be considerably less than the 30-year period previously accepted. We have made a determination of the half-life of tritium and obtained a value of 12.46 ± 0.2 years, in agreement with the 12.1 ± 0.5 years reported by Novick. In addition, we have measured the average energy of the tritium decay and found it to be 5.69 ± 0.06 kev.

To determine the half-life of tritium, a sample containing a measured amount of the isotope was prepared and the rate of He^3 evolution, and thus the disintegration rate, of the sample measured. The average energy of the decay was determined by calorimetric study of the quantitative sample.