a current regulated magnet with 8-in. pole faces operating near 1500 gauss and the others with a battery operated magnet with 10-in. pole faces operating near 1900 gauss. The ratios of the resonance frequencies in the same field were found to be

$$\nu(\mathrm{Tl}^{203})/\nu(\mathrm{H}^1) = 0.5714 \pm 0.0001,$$
$$\nu(\mathrm{Tl}^{205})/\nu(\mathrm{H}^1) = 0.5770 \pm 0.0001,$$
$$\nu(\mathrm{Tl}^{203})/\nu(\mathrm{Tl}^{205}) = 0.9903 \pm 0.0002.$$

This result for Tl^{205} agrees within experimental errors with that given by Poss in a previous letter.[3] He did not make precise measurements on the Tl^{203} resonance because of a low signal-to-noise ratio but stated that for the same frequency its resonance could be found at a field one percent lower than that required for Tl^{205}. In the present experiment the signal-to-noise ratio for the Tl^{203} resonance was about ten, and thus allowed a considerably more accurate location of the resonance frequency.

The magnetic moments of the nuclei of both thallium isotopes were found to be positive, and their integrated resonance amplitudes were each consistent with a spin of $\frac{1}{2}$, as given by spectroscopic data.[4] If the magnetic moment of the proton is taken to be $(2.7928 \pm 0.0008)\mu_N$[5] and a correction for electronic diamagnetism is made,[6] which for this computation has been assigned an error of 15 percent, then

$$\mu(\mathrm{Tl}^{203}) = (1.614 \pm 0.003)\mu_N,$$
$$\mu(\mathrm{Tl}^{205}) = (1.629 \pm 0.003)\mu_N.$$

The ratio $\mu(\mathrm{Tl}^{203})/\mu(\mathrm{Tl}^{205}) = 0.9903 \pm 0.0002$ is, of course, much more accurately known.[7]

* Assisted by the Joint Program of the ONR and the AEC.
1 R. V. Pound, Phys. Rev. 72, 527 (1947).
2 Note Eq. (40b) in the paper by F. Bloch, Phys. Rev. 70, 460 (1946).
3 H. L. Poss, Phys. Rev. 72, 637 (1947).
4 H. Schüler and J. E. Keyston, Zeits. f. Physik 70, 1 (1931); H. Schüler and T. Schmidt, Zeits. f. Physik 104, 468 (1937).
5 This value differs from the value (2.7896±0.0008) given by S. Millman and P. Kusch, Phys. Rev. 60, 91 (1941), by the correction for the magnetic moment of the electron $[1+(\alpha/2\pi)]$ suggested by J. Schwinger, Phys. Rev. 73, 416 (1941).
6 W. E. Lamb, Jr., Phys. Rev. 60, 817 (1941).
7 Upon completion of this work, our attention was drawn to more recent results by Poss, reported in the Quarterly Progress Report of the Research Laboratory of Electronics, Massachusetts Institute of Technology, July 15, 1948, p. 32. The results given above are in substantial agreement with those of Poss.

H^3 and the Mass of the Neutrino

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December 20, 1948

Last year Konopinski[1] pointed out that, on the basis of data available at that time concerning the half-life[2] and maximum beta-ray energy[3] of tritium, the value of $|M|^2ft$ for H^3 was roughly 1/10 as large as for He^6, if zero neutrino rest mass was assumed. To remove this discrepancy with beta-decay theory, which predicts the same order of magnitude of $|M|^2ft$ for allowed transitions in all nuclei, Konopinski found it necessary to take the neutrino rest mass to be a few percent of that of the electron.

We should like to point out that more recent work on the half-life of tritium[4] and on its beta-spectrum[5] gives results which appear to remove the above-mentioned discrepancy with a zero neutrino mass. If one takes the upper limit of the tritium spectrum[5] to be 17 kev, one finds[6] for a zero neutrino mass, taking into account the Coulomb field, $f = 2.2 \times 10^{-6}$. With a half-life[4] $t = 12$ years and with $|M|^2 = 3$, this gives $|M|^2ft = 2500$ sec., which is of the same order of magnitude as the value 5760 sec. given by Konopinski[1] for He^6.

This result is in agreement with the conclusions of several workers[5,7] concerning the neutrino mass based on the shapes of beta-energy distribution curves near their upper limits.

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4 Aaron Novick, Phys. Rev. 72, 972 (1947).
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γ-Radiation from Au^{198}

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December 14, 1948

Several papers[1] have lately been published in this journal regarding the γ-radiation following the β-disintegration of Au^{198}. We have made a careful study of the γ-radiation in order to be able to find any γ-radiation besides the well-known γ-ray at 411 kev. The investigation was performed with our new double focusing spectrometer ($\rho = 50$ cm) (in course of publication). The resolving power of the spectrometer was set to 0.8 percent and the lead converter used was only 3.7μ thick in order to make full use of the resolving power of the instrument itself. The results are shown in Fig. 1. The Compton distribution, the *K*, *L*, and *M* photo-lines of the 411-kev γ-ray, is clearly seen. Levy and Greuling[2] have reported γ-rays of 157 and 207 kev with an intensity of ≤15 percent of the 411-kev ray. We have paid special attention to the region 800–1250 $H\rho$, where the *K* photo-lines of these rays should be

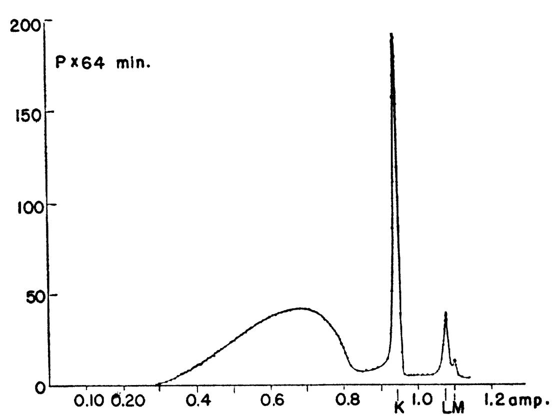

FIG. 1. Secondary electron spectrum, Au^{198}.

found but, as is seen in Fig. 1, we are unable to detect them. We believe that we can put an upper limit for the intensity of these rays to be 2 percent of the 411-kev ray.

Furthermore, a γ-ray of only 1 or 2 percent abundance could not explain the coincidence effect found in some earlier cases. On the other hand, it might be questioned if this effect is real (see E. T. Jurney[1]). The rather extensive $\gamma-\gamma$-coincidence measurements we have performed in this laboratory also give a small $\gamma-\gamma$-coincidence effect but, if one compares this effect with the spurious $\gamma-\gamma$-effect obtained from Fe^{59} with two uncorrelated γ-rays, the whole effect just disappears. The magnitude of this extra coincidence effect, clearly demonstrated in Fe^{59}, may very well depend on the actual experimental arrangement but has to be taken into account. In our arrangement which otherwise is designed to prevent coincidences due to scattering, the spurious effect with Fe^{59} decreases when lead foil is wrapped around our γ-tubes and disappears almost completely when the lead thickness is 1 mm.

We have also measured the primary β-spectrum in order to determine the internal conversion coefficients of the K, L, and M lines of the 411-kev radiation. The sample obtained from Harwell was evaporated in a thin layer to eliminate absorption effects. We obtained $\alpha_K=3.0$ percent; $\alpha_L=1.0$ percent; $\alpha_M\sim 0.3$ percent.

To get a precise determination of the γ-line energy we put Cu^{64} and Au^{198} in the same converter and measured the L photo-line from Au^{198} against the K photo-line of the 510.8-kev radiation from Cu^{64}. These two lines then formed a rather close "doublet" which makes a comparison of the two energies reliable. In this way we obtained a value for the Au^{198} line to be 411.0 ± 1 kev, in close agreement with Dumond's[3] crystal value. We believe that this kind of measurement in the β-spectrometer can be made still more accurate in the near future.

[1] For references see E. T. Jurney, Phys. Rev. 74, 1049 (1948).
[2] P. Levy and E. Greuling, Phys. Rev. 73, 83 (1948).
[3] J. Dumond, D. Lind, and B. Watson, Phys. Rev. 73, 1392 (1948).

V-2 Cloud-Chamber Observation of a Multiply Charged Primary Cosmic Ray*

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December 13, 1948

A SIX-INCH cloud chamber was flown in a V-2 to a height of 159 km (99 miles) on January 22, 1948. The chamber was six inches in diameter and contained argon and alcohol-water vapor at two atmospheres pressure. Two lead plates, each 1 cm thick, crossed the chamber which was illuminated for a depth of one inch. Stereo photographs were taken at 25-second intervals.

Since the V-2 was in free fall after its fuel burned out, droplets formed in the chamber remained stationary until the gas was recompressed. This reduced several sources of track distortion, but eliminated the cleaning out by falling droplets of uncharged condensation nuclei. As a result, a progressive fogging took place rendering the later photographs unusable.

Figure 1 is half a stereo photograph taken 175 seconds after launching. The height was 145 km and the outside atmospheric pressure $\sim 10^{-5}$ mm Hg. Besides the background fog, one may observe a large number of fast particles, for example, at b and c, many of which have a common origin. However, the most prominent particle (marked a) is not associated with any observable shower. It traverses both lead plates and ionizes heavily. Its scattering is less than the perceptible limit which we take conservatively as 1°. We may test the possibility that it is a proton by noting whether the momentum required for penetration of the lead is consistent with the heavy ionization and small scattering. Its path in plate II is 1.6 cm. Considering only this plate, it must have a ratio of incident momentum to characteristic momentum of $p/\mu c\geq 0.48$[1] corresponding to an energy $E\geq 102$ Mev. The incident ionization relative to the minimum which a proton can have[2] is then $I/I_{\min}\leq 3.3$. Inspection of the photograph does not permit an assumption of $I/I_{\min.}<\sim 3$. Then we must have $p/\mu c<0.53$. For the latter value, the expected scattering may be computed. The differential mean square scattering for a particle of mass μ and charge number z in traversing a thickness dx of material may be put in the form $d(\theta^2)_{\mathrm{Av}}=(z^2/\mu^2)f(p/\mu c)dx$.[2,3] By graphical integration one obtains $\Delta\theta=5.0°$ as the expected r.m.s. projected angle of scattering in 1.6 cm Pb. Since the distribution in angle is Gaussian,[3] the probability P of observing scattering of less than 1° may be calculated from a table of the error integral. One gets $P(<1°)=0.16$. It is therefore possible, but not likely, that the particle is a proton.

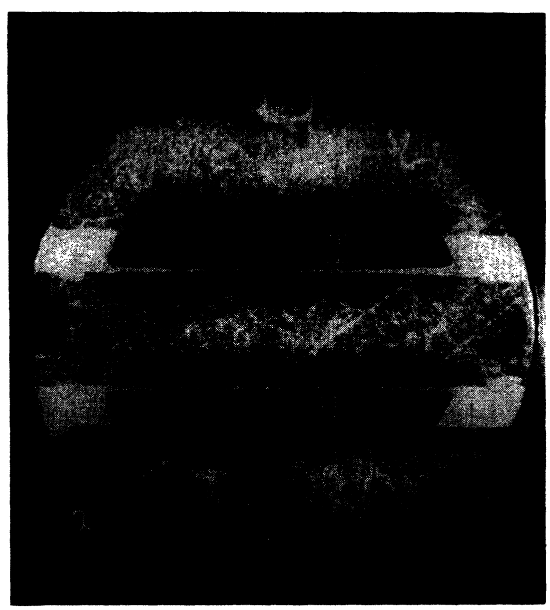

Fig. 1. Cloud-chamber photograph at height of 145 km.