spin value, γ the gyromagnetic ratio, ω_0 the resonance frequency, H_s the amplitude of the sweep field, H_1 the half-amplitude of the rf exciting field, and T_1 and T_2 the longitudinal and transversal relaxation times, respectively. Based on the expression (2), the spin determination for O^{17} was carried out with samples of natural water and of O^{17}-enriched water in solutions of either 0.0002-molar concentration of $MnSO_4$ or 0.025-molar concentration of $Fe(NO_3)_3$. A sample of 1.5 percent D_2O in 3-molar concentration of $MnSO_4$ was used for the comparison. In all experiments H_s was chosen as 0.085 gauss and was considerably smaller than the line widths of O^{17} and D^2 signals (about 0.4 gauss) which were mostly due to the field inhomogeneity of the magnet. The dependence of the signal amplitudes of O^{17} and D^2 on the rf field H_1 was found to fit the theoretical expression (2) very well and was used to determine the value T_1T_2. The value of T_2 was given by the measured line width of the signal. Three independent measurements with different samples in different magnetic fields yielded the value 2.44 ± 0.25 for the spin of O^{17}. Considering that the nearest other possible spin values 3/2 and 7/2 are well outside the experimental value, this result indicates that the spin of O^{17} is

$$I(O^{17}) = 2.5 = 5/2. \qquad (3)$$

In deriving this result it has evidently been assumed that the signal amplitude is, under otherwise identical conditions, proportional to the expression (2). Although there are certainly cases (for example, in the presence of a line structure) where the underlying simplified theory would not hold, it seems experimentally well supported in this case both by the observed line shapes and by the fact that the observed dependence on H_1 of the signal amplitude is in very good agreement with (2).

Because of the large field inhomogeneity over the sample region (about 0.3 gauss) the signals were sufficiently broad for both O^{17} and D^2. In the case of O^{17} the ratio of T_1/T_2 was about 7 for the samples used for the spin determination. It was observed further that the addition of paramagnetic ions does not much affect the thermal relaxation time T_1 of O^{17} nuclei, but that it broadens the line considerably. A 0.001-molar concentration of $MnSO_4$ would give a line width of about 1 gauss for O^{17}, but did not give an appreciable effect on D^2. A further investigation of this abnormal relaxation mechanism of O^{17} in the presence of paramagnetic ions is in progress.

Using the frequency ratio (1), the spin value (3), and the observed negative sign, the value

$$\mu(O^{17}) = -1.8928\pm0.00019 \text{ nm} \qquad (4)$$

was obtained for the magnetic moment of O^{17}. In deriving the value (4) we have further used the value 2.79245 ± 0.00020 nm for the proton moment recently determined by Bloch and Jeffries[3] and the ratio of the deuteron moment to the proton moment obtained by Levinthal.[4]

The spin value 5/2 with the negative moment approximately equal to the neutron moment assigns a $d_{5/2}$ orbit to the odd neutron of O^{17} as one would expect from the shell model proposed by Mayer[5] and Haxel, Jensen, and Suess.[6] This assignment disagrees with that of Feenberg and Hammack[7] who predicted an $s_{1/2}$ orbit for the ground state of O^{17}.

The authors would like to thank Professor F. Bloch for his valuable comments and constant encouragement throughout this work. Thanks are also due to Mr. Russell Ball at the Radiation Laboratory in Berkeley, California for the loan of the water enriched in O^{17} and to Dr. D. P. Stevenson at the Shell Development Company in Emeryville, California for the mass spectrometric analyses of the abundance of O^{17} in the enriched water.

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Scintillation Counting of Cosmic-Ray Particles*

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SCINTILLATION counters have the property of producing pulses of amplitude proportional to the energy lost in the scintillator. In order to use scintillators to study the primary heavy nuclei in cosmic rays, we have investigated several experimental arrangements. When a scintillation counter is used as one of the counters in a telescope, the distribution of pulse amplitudes is broadened by the following factors: (a) The statistical fluctuation in energy loss; (*b*) the variation in light collection in the counter; (*c*) the variation in path length through the counter; and (*d*) the statistics of the photo-electrons in the multiplier.

The effect of photo-electron statistics can usually be made very small by good light collection and by the use of a good scintillator. We have found that pyrene dissolved in xylene is a very satisfactory scintillation material. This solution gives pulses with a 5819 multiplier which are about half the size of those from terphenyl in xylene. The fluorescent light from pyrene is light green, however, and suffers negligible absorption in the xylene or in impurities in the zylene. The maximum light output is obtained at a pyrene concentration of 8 g/liter of zylene.

The geometrical arrangement of the scintillation counter is shown in Fig. 1. The multiplier looks into the glass "T" tube which is painted with magnesium oxide on the outside of the glass. Whenever a triple coincidence occurs in the Geiger counter telescope, the pulse from the scintillation counter is measured. The geometry can be improved by making the active region of the scintillation counter square instead of round in cross section and by decreasing the angle subtended by the Geiger counters.

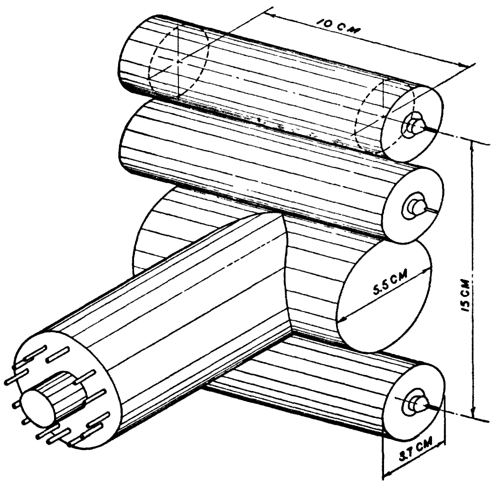

FIG. 1. Scintillation counter geometry.

It has been shown by Landau[1] and by Symon[2] that large fluctuations in the energy loss of monoenergetic charged particles are to be expected if the particles lose only a fraction of their energy in the detector. Whittemore and Street[3] have shown that the experimental distribution obtained with a crystal counter resembles the theoretical curve. In their case, nonuniform parts of the crystal apparently gave more small pulses than were expected from the theory. Figure 2 shows a distribution of sea-level mesons obtained with the scintillation counter telescope. The curve of Fig. 2 was taken with a smaller solid angle than that represented by the telescope of Fig. 1. The contribution to the spread in pulse heights by photo-electron statistics, geometry, and light collection was less than 8 percent. The average energy loss in Fig. 2 corresponds to 9 Mev. The shape and half-width of the distribution agree quite well with the theoretical calculation. Professor Charles

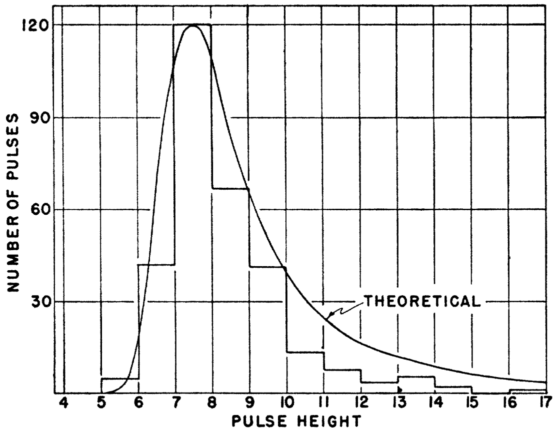

FIG. 2. Theoretical (smooth curve) and experimental pulse distributions.

Critchfield has pointed out to us that because the large pulses come from high energy δ-rays, all of which would not stop in the liquid, the experimental curve should drop off faster on the high energy side than the theoretical curve. The statistics of the data are not good enough to decide this point.

Two types of end-window photo-multipliers are suitable for use in this type of counter; the English Electrical and Musical Industries VX5031 and the R.C.A. 5819. The E.M.I. tube which we used was preferred, because its signal to noise ratio was about 10 times better than that of any of the 5819 tubes which we tried.

We are indebted to Professor Walter Lauer for supplying us with pure pyrene.

* Assisted by the joint program of the ONR and AEC.

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A Scintillation Counter Measurement of Heavy Nuclei*

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A SCINTILLATION counter telescope of the type described in the previous latter[1] was flown on October 4, 1950, to an altitude of 105,000 ft on a "Skyhook" balloon. The residual atmosphere above the balloon was less than 10 g/cm^2 for a period of 5 hr.

The scintillation pulses from the counter were displayed on oscilloscopes in the balloon gondola whenever a coincidence count occurred in the Geiger telescope. Pulse amplitudes over a range of 200 to 1 could be recorded. The oscilloscopes on which the pulses were displayed were photographed continuously, and at one-minute intervals the reading of a Wallace and Tiernan low pressure barometer and a "total count" recorder were also photographed. During the flight approximately 30,000 pulses were recorded.

Because of the stage of development of the scintillation counter at the time of the flight, the resolution of the equipment did not approach the Landau statistical limit. It was not possible, therefore, to resolve adjacent atomic numbers in this flight because of the poor resolution and the fact that at 55°N latitude the cut-off energy imposed by the earth's magnetic field is so low that slow particles of low atomic number can suffer a greater energy loss in the scintillation counter than relativistic particles of higher atomic number.

The energy loss in the scintillation counter is proportional to Z^2/V^2, where Z is the atomic number and V is the particle velocity.

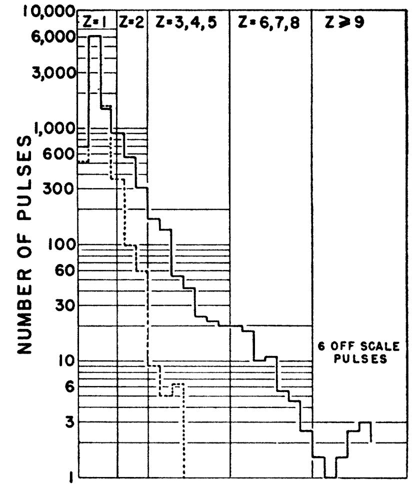

FIG. 1. Atomic number histogram.

A differential pulse amplitude distribution would, therefore, have a scale of abscissas proportional to Z^2. We have changed the scale in Fig. 1 so that we obtain a frequency distribution of pulses as a function of atomic number. The dotted curve in Fig. 1 gives the distribution obtained during the ascent from 500 g/cm^2 to 100 g/cm^2. The difference between the curves shows clearly the contribution of multiply charged primaries at the top of the atmosphere. Since one knows the shape of the curve corresponding to singly charged particles, it is possible by successive subtraction to estimate the number of pulses in each interval of atomic number. These results are shown in Table I. The actual number of pulses is included to show the magnitude of the statistical errors.

TABLE I. Measured abundancies of nuclei.

Element	Number of pulses	Flux (particles/cm^2-sec-steradian)
H	8740	1.9×10^{-1}
He	1257	2.8×10^{-2}
Li, Be, and B+Stars	387	8.4×10^{-3}
C, N, O+Stars	76	1.6×10^{-3}
$Z\geqq9$+Stars	20	4.3×10^{-4}

The total flux of 0.23 parts/cm^2-sec-steradian is in reasonable agreement with the results of Winckler and Stroud.[2] The hydrogen-helium ratio of 7 is higher than that previously reported.[3-5] The last three groups in the table must include pulses arising from stars produced by primary protons in the scintillator. Emulsion work leads one to believe that most of these stars would give pulses in the region of the lithium, beryllium, boron group. The energy of such a star would be about 150 Mev. If we assume that all the pulses in the lithium, beryllium, boron region are due to stars, we can calculate the product of $\eta\sigma$, where η is the efficiency of the counter telescope for triggering on a star produced in the scintillator, and σ is the cross section for star production by primary protons. On this assumption, if η is 1, then σ would be half geometric cross section. The abundance of carbon, nitrogen, and oxygen and of $Z\geqq9$ agrees well with the values obtained in photographic plates.[3,5,6] This leads us to believe that stars do not contribute appreciably in this region of pulses.

During the period of the flight there was a variation with time in the frequency of large pulses. This variation seems statistically significant and appears to be further evidence for a change in the flux of heavy nuclei either as a diurnal effect or because of solar activity. At the same time that the heavy nuclei increased, the pulse distribution in the proton—α-particle region indicated the presence of more α-particles. These results are indicated in Fig. 2