parity. This is an allowed transition and according to Nordheim's[9] rule number 3 should, in general, have values of log (ft) from 4.8 to 5.5. The experimental evidence presented in this paper indicate that the transition is allowed and that the value of log (ft) is 5.7. With the above spin assignments this is in good agreement with the predictions of the nuclear shell model. These spin assignments are in agreement with those given by Nordheim.[14]

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1 E. P. Steinberg and D. W. Engelkemeier, Plutonium Project Report CC-2310, p. 31 (January, 1945), unpublished.
2 Steinberg, Winsberg, and Engelkemeier, Plutonium Project Report CC-2379, p. 5 (November, 1944), unpublished.
3 Mandeville, Woo, Scherb, Keighton, and Shapiro, Phys. Rev. **75**, 1528 (1949).
4 L. E. Glendenin, Nucleonics **2**, No. 1, 12 (1948).
5 Jensen, Laslett, and Pratt, Phys. Rev. **75**, 458 (1949).
6 W. J. Heiman, private communication.
7 M. G. Mayer, Phys. Rev. **78**, 16 (1950).
8 Laslett, Jensen, and Paskin, Phys. Rev. **79**, 412 (1950).
9 L. W. Nordheim, Phys. Rev. **78**, 294 (1950).
10 Strandberg, Wentink, and Hill, Phys. Rev. **75**, 827 (1949).
11 J. E. Mack and O. H. Arroe, Phys. Rev. **76**, 173 (1949).
12 Geschwind, Minden, and Townes, Phys. Rev. **78**, 174 (1950).
13 J. E. Mack, Revs. Modern Phys. **22**, 64 (1950).
14 L. W. Nordheim, *Tables for β-Decay Systematics*, distributed privately.

On the Existence of a One-Mev Energy Level in C^{13}

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THERE has been considerable discussion recently in the literature concerning the existence of an energy state of C^{13} at 0.8 to 1.0 Mev. A level at 0.8 Mev was first reported to be observed in the $B^{10}(\alpha, p)$ reaction; more recently it was observed by Roy,[1] using polonium α-particles. On the other hand, Creagan,[2] using α-particles produced in the cyclotron, failed to observe such a level. The $C^{12}(d, p)$ reaction was studied in detail by Heydenburg, *et al.*,[3] and by Buechner, *et al.*,[4] the latter using magnetic analysis; but neither of them found any evidence of a C^{13} level in this region. Quite recently, however, Boyer[5] and Berlman[6] claim to have observed a level at 1 Mev in a $C^{12}(d, p)$ reaction, using deuterons of 10 and 14 Mev.

We have made a detailed search for this level in the course of a study of energy states of C^{13}, which will be published elsewhere. The levels were excited using 8-Mev deuterons from the Liverpool cyclotron, and the protons corresponding to the various states of excitation of C^{13} were observed by means of photographic emulsions. The target used was acetylene at a pressure of 10 cm, and care was taken to eliminate contaminations. Although large areas of the plates were scanned and several angles of emission studied, we could find no trace of a C^{13} level between the ground state and the 3.11-Mev excited state.

The observation of such level by other workers can possibly be explained as due to oxygen contamination. It is extremely difficult to get rid of traces of oxygen; even in our experiments, where a gaseous target was employed and the emulsions were evacuated for several hours to drive off the water, we still observe some tracks corresponding to the ground state and the 0.88-Mev excited state of O^{17}, from the reaction $O^{16}(d, p)$. This can be seen in Fig. 1, which shows a section of the histogram obtained at an angle of emission of 75°. Between the ground state and first excited state of C^{13} there are only a few tracks, and almost all of them can be attributed to the two states of O^{17} if we assume the presence of oxygen contamination at a pressure of $\frac{1}{2}$ mm. Similar results were obtained for angles of emission 40°, 60°, 90°, and 120°; in each case the ratio of the numbers of tracks of the two oxygen groups agrees, within the statistical error, with that expected from the angular distribution of the protons from the $O^{16}(d, p)$ reaction.[7] The position of the supposed 1-Mev level is also indicated on Fig. 1. At larger angles of emission the group of protons corresponding to such a level will fall nearer the 0.88-Mev oxygen group which can, therefore, easily be mistaken for it. We conclude that if a C^{13} level exists in the region of 1 Mev, its probability of excitation in a (d, p) reaction is at least 200 times lower than that corresponding to the ground state.

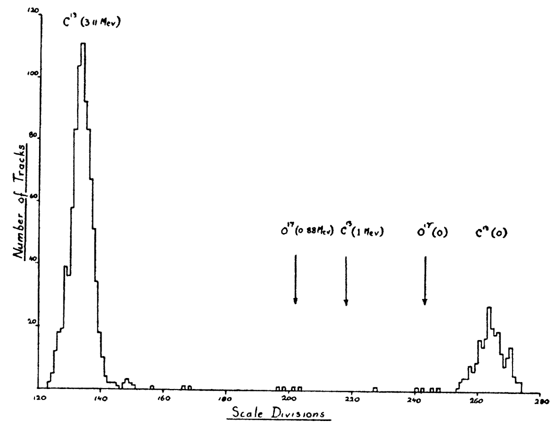

FIG. 1. Section of histogram of protons emitted at an angle 75°. One division = 1.73 microns.

1 R. R. Roy, Phys. Rev. **75**, 1775 (1949).
2 R. J. Creagan, Phys. Rev. **76**, 1769 (1949).
3 Heydenburg, Inglis, Whitehead, and Hafner, Phys. Rev. **75**, 1147 (1949).
4 Buechner, Strait, Sperduto, and Malm, Phys. Rev. **76**, 1543 (1949).
5 K. Boyer, Phys. Rev. **78**, 345 (1950).
6 I. B. Berlman, Phys. Rev. **79**, 411 (1950).
7 Burrows, Gibson, and Rotblat, Phys. Rev. **80**, 1094 (1950).

The Ratio of Electrons to Mesons 1100 Feet Underground*

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THERE have been experiments that apparently contradict the usual assumption that cosmic-ray energy is carried underground primarily by μ-mesons.[1] The present experiments on the absorption of the hard and soft radiation and on the nature of the soft radiation were designed to test whether or not there really are any contradictions with the assumption of μ-mesons. The results on absorption in large thicknesses of lead and cloud-chamber observations,[2] both of which support the assumption of μ-mesons, have been reported previously.

The radiation emerging from a salt layer ~150 cm thick that was 700 cm above the apparatus in a salt mine at a depth of 8.5×10^4 g/cm^2 was measured by coincidences between two trays of G-M counters. (Three trays were used in the auxiliary experiment to determine the effect of local radiation.) The low energy cosmic-ray particles were identified as electrons by comparison of the absorptions by lead and by carbon, and their energy distribution was determined from their range distribution in carbon.

The coincidence rates were converted to flux of particles through the apparatus by making small corrections for side showers, knock-on electrons produced in the material near the counters or in the counter walls, multiple events through the trays, and coincidences produced by gamma-rays from radioactive materials. Auxiliary experiments gave the data required for making the corrections.

The meson flux was subtracted from the total flux in order to obtain the flux of electrons. The ratio of electron to meson flux is shown in Fig. 1. If the meson spectrum is independent of zenith angle, the electron to meson ratio is independent of zenith angle and the ratio of electron to meson flux through the entire apparatus is the same as the ratio of electron to meson intensity at a given angle. Since the meson energy spectrum underground is probably a function of zenith angle and since Wilson's data[3] give information concerning intensities near the vertical, we should compare vertical intensities of electrons and mesons. This was done for the case of electrons with energy greater than 3 Mev as follows. From the flux determinations for six different tray separations, all with 15 cm of lead absorber, the zenith angle distribution of meson intensity was obtained for angles near the vertical. If we assume that the distribution has the form

$$I(\theta)=I_v \cos^n\theta,$$

the constants have the values

$$I_v=2.17\pm0.02\times10^{-6}\ \text{sec}^{-1}\ \text{sterad}^{-1}\ \text{cm}^{-1}$$
$$n=2.8\pm0.1.$$

Similarly, the distribution for electrons of energy greater than 3 Mev has the constants

$$I_v=0.92\pm0.06\times10^{-6}\ \text{sec}^{-1}\ \text{sterad}^{-1}\ \text{cm}^{-2}$$
$$n=1.4\pm0.3.$$

The meson vertical intensity was subtracted from the total vertical intensity to give the electron vertical intensity for $E>3$ Mev. The intensity distribution for electrons of $E>3$ Mev is an average for electrons of many energies. The higher energy electrons preserve the original direction of the parent mesons and thus may have an angular distribution more nearly like the mesons. (If the meson spectrum is independent of zenith angle, the high energy electrons have the same angular distribution as the mesons.) At any rate, we obtain upper or lower limits for the spectrum of electrons from the vertical by assuming, respectively, that the angular distribution of all electrons is the same as for the mesons or that it is the same as the average value for all electrons with $E>3$ Mev. The limiting values are shown in Fig. 1.

The number of electron secondaries to be expected has been calculated using the method of Williams.[4] This number depends on the local meson spectrum, which can be obtained, at least approximately, from Wilson's data for intensities at depths greater than the present observation depth.[3] The knock-on contribution does not depend critically on the assumed local meson spectrum and is shown in Fig. 1. On the other hand, the radiation contribution to secondary photons and thence to secondary electrons does depend strongly on the local meson spectrum. If we use a meson spectrum based on Wilson's data and on the assumption that the

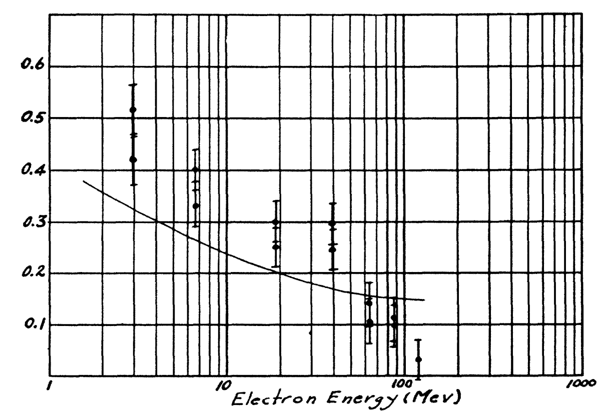

FIG. 1. The integral spectrum for electrons in terms of number of electrons per meson. The curve is the expected contribution by knock-on electrons and their progeny. The inclusion of the contribution by radiation would roughly double the height of the curve at low energies. The experimental points are believed to represent upper and lower limits.

radiation losses are small enough so that they can simply be added to the collision losses, the contribution to the secondary electrons by radiation by mesons of spin one-half is about equal to the knock-on contribution at low electron energies and becomes greater than the knock-on contribution at high electron energies.

Although the measured number of electrons is somewhat less than predicted, we believe that the uncertainty in the local meson spectrum accounts for the discrepancy and that there is no reason to believe that the penetrating component does not consist mostly of μ mesons. The experiment was made possible by the cooperation of the management of the International Salt Company and of the personnel at the Detroit mine.

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[1] J. Barnothy and M. Forro, Phys. Rev. **74**, 1300 (1948).
[2] L. Tiffany and W. Hazen, Phys. Rev. **77**, 849 (1950); Randall, Sherman, and Hazen, Phys. Rev. **79**, 905 (1950).
[3] V. C. Wilson, Phys. Rev. **53**, 377 (1938).
[4] E. J. Williams, Proc. Camb. Phil. Soc. **36**, 183 (1940).

An Investigation of the 2943-cm^{-1} Line of the Solar Spectrum*

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MIDWAY between the -7 and the -8 lines of the ν_3 fundamental band of methane lies an interesting line which has been detected by several investigators.[1-3] Mohler and Pierce[2] measured the wavelength of this line very accurately and attributed the absorption to silicon and magnesium in the sun. Subsequently, Migeotte[4] cast doubt on this assignment by showing that the line did not appear in solar spectra taken at his laboratory in the Swiss Alps. More recently, spectra of highly humid atmosphere obtained at this laboratory during the past summer with a searchlight source failed to reveal this line, although a number of normally weaker water lines were evident.[5] Earlier unpublished[6] work by one of us had indicated the possible intrusion of extraneous lines of methane into this region as well as the sensitivity of the 2943-cm^{-1} line to the insertion of methane into the solar beam. Because of other absorption in the atmosphere in this region, however, this evidence was inconclusive; it appeared advisable, therefore, to obtain a pure spectrum of methane of sufficient concentration to indicate whether or not this was a weak methane line.

Dr. Shirleigh Silverman, of the Applied Physics Laboratory, Johns Hopkins University at Silver Spring, kindly offered the use of his high resolution vacuum spectrograph to obtain this spectrum. The region of the *P*-branch of this methane band was scanned with a short cell filled with chemically pure methane at atmospheric pressure. Between the -7 and -8 lines of the band of the 2943-cm^{-1} line appeared clearly; with the cell filled with air this line, as well as the -7 and -8 lines, vanished. We conclude from this that the 2943-cm^{-1} line is definitely due to methane.

Among the other main methane lines occurred occasional weak absorption which bore a resemblance to the "background" lines of the early methane spectrum of Nielsen and Nielsen.[7] Although these authors did not identify them definitely with methane, the agreement between many of their lines and ours indicates that this indeed may be their origin, perhaps owing to nearby combination or overtone bands. It is planned to study these weaker lines in more detail in the near future.

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[1] Migeotte, Astrophys. J. **107**, 400 (1948).
[2] Mohler and Pierce, Astron. Soc. Pacific, **61**, 221 (1949).
[3] Benesch, Strong, and Benedict, ONR Progress Report, August 1, 1950.
[4] Talk at Ohio State Symposium on Molecular Spectroscopy, June, 1950.
[5] Benesch, Elder, and Strong, ONR Progress Report, September 15, 1950.
[6] Solar spectra recorded by W. Benesch, October, 1949.
[7] Nielsen and Nielsen, Phys. Rev. **48**, 864 (1935).