about 15/1, while the corresponding ratio of meson intensity is only 2/1.

Hence we may say that it appears almost certain that high energy nucleons and $\sigma$-mesons play the principal role in the creation of these stars. The latter may be spoken of as "local indicator" of these components of cosmic radiation.

If this assumption is justified, we may deduce, by comparing the measurements under air and lead, the following value for the total cross section of this component:

$$\sigma \cong 3A^{\frac{2}{3}} \times 10^{-26}\ \mathrm{cm}^2.$$

[1] C. F. Powell, G. P. S. Occhialini, and C. M. G. Lattes, Nature **159**, 186 (1947); **159**, 694 (1947); **160**, 453 (1947); **160**, 486 (1947).
[2] H. Wambacher, Sitz. Akad. Wiss. Wien, IIA, **149**, 157 (1940).
[3] We are very indebted to Dr. A. Persano for his invaluable help in the performance of the flights.
[4] W. Heitler, C. F. Powell, and H. Heitler, Nature **146**, 65 (1940).
[5] G. Cortini, A. Manfredini, and A. Persano, Nuovo Cimento, in press.
[6] D. H. Perkins, Nature **160**, 707 (1947).
[7] Communication by Professor L. W. Alvarez at the Zurich Congress, July 1948.
[8] H. Bridge and B. Rossi, Phys. Rev. **71**, 379 (1947); H. Bridge, B. Rossi, and R. Williams, Phys. Rev. **72**, 257 (1947); H. E. Tatel and J. A. Van Allen, Phys. Rev. **73**, 87 (1948).

## Preliminary Analysis of the Microwave Spectrum of Ethylene Oxide*

R. G. SHULMAN, B. P. DAILEY, AND C. H. TOWNES
*Columbia University, New York, New York*
August 23, 1948

FOUR strong lines of the pure rotational spectrum of the asymmetric rotor, ethylene oxide, have been observed in the region near 24,000 Mc/sec. (see Table I). The frequencies of the lines and their Stark effects allow identification of the transitions and determination of the moments of inertia of the molecule.

The Stark splitting is of the form $\Delta\nu = \mu^2 E^2 (A + BM^2)$ where $\Delta\nu$ is the difference between the frequencies of the Stark component and the undisplaced line. The number of components and their relative spacings allow a determination of the lower value of $J$ involved in each transition.

TABLE I. Ethylene oxide absorption lines.

| Frequency Mc/sec. | Designation |
|---|---|
| 23,160 | $3_1-3_3$ |
| 23,614 | $3_{-1}-3_1$ |
| 24,855 | $4_0-4_2$ |
| 24,948 | $2_{-2}-2_0$ |

Relative intensities of the components are proportional to $M^2$, which indicates that $\Delta \cdot J = 0$ for all four transitions.[1]

For $\Delta J = 0$, $\nu_{J\tau;J\tau'} = (a-c)/2(E_\tau{}^J - E_{\tau'}{}^J)$, where $E_\tau{}^J$ is a tabulated function[2] of $J$, $\tau$, and $\kappa$. Only values of $\kappa = \pm 0.395$ allow fitting the observed lines in frequency, and the Stark effect shows that $\kappa = +0.395$ is the correct choise between these two values. In addition to determining $\kappa$, the line frequencies give $(a-c)/2 = 0.1898$ cm$^{-1}$.

The Stark pattern of the $2_{-2}-2_0$ transition is very sensitive to the ratio of $(a-c)/(a+c)$. Changes of 1 percent in the value of this ratio vary the ratio of the Stark effect coefficients $A/B$ by 3 percent, giving $(a-c)/(a+c) = 0.2756 \pm 0.003$, and $(a+c)/2 = 0.689 \pm 0.007$ cm$^{-1}$.

For the analysis, ethylene oxide was considered to be rigid and the effective moments of inertia rather than the equilibrium moments are determined. They are:

$$I_A = 31.9 \times 10^{-40}\ \mathrm{g\ cm}^2,$$
$$I_B = 36.7 \times 10^{-40}\ \mathrm{g\ cm}^2,$$
$$I_C = 56.7 \times 10^{-40}\ \mathrm{g\ cm}^2.$$

As a check on the structure, the Stark patterns of the $3_3-3_1$, $3_1-3_{-1}$, and $4_2-4_0$ transitions were calculated and the ratios of various coefficients involved were compared with the experimental values (see Table II).

TABLE II. Ratios of Stark effect coefficients for observed lines. [Stark displacement $\Delta\nu = \mu^2 E^2 (A + BM^2)$.]

| Ratio | Calculated | Observed |
|---|---|---|
| $A_{3_1-3_3}/B_{3_1-3_3}$ | 0.69 | 0.69 |
| $A_{3_{-1}-3_1}/B_{3_{-1}-3_1}$ | −0.20 | −0.18 |
| $B_{3_1-3_3}/B_{3_{-1}-3_1}$ | 0.67 | 0.66 |
| $A_{4_0-4_2}/B_{4_0-4_2}$ | 0.002 | 0.01 |
| $A_{2_{-2}-2_0}/B_{2_{-2}-2_0}$ | 0.233 | 0.233 |
| $B_{4_0-4_2}/A_{2_{-2}-2_0}$ | −0.62 | −0.62 |

If the C−H distance is assumed to be 1.09A, then the H−C−H angle is 121°.

Further work is contemplated to study isotopic species and to obtain more accurate molecular constants.

* Work supported by the Signal Corps.
[1] S. Golden and E. B. Wilson, Jr., J. Chem. Phys. **16**, 669 (1948).
[2] G. W. King, R. M. Hainer, and P. C. Cross, J. Chem. Phys. **11**, 27 (1943).

## On the Production of Showers of Penetrating Particles

H. A. MEYER, G. SCHWACHHEIM, AND ANDREA WATAGHIN
*Departamento de Física, Universidade de São Paulo, Brasil*
August 26, 1948

THE purpose of the present experiments[1] was to study the cross section for the production of penetrating showers in various materials.

The penetrating showers were detected by a pair of "telescopes" shielded by lead from all sides (of the type used by G. Wataghin[2]). The registered radiation had a minimum range of 18 cm Pb. The telescopes were separated by 16 cm Pb.

Two series of measurements were planned. In the first one we distributed an equal number of nucleons (equal masses) of different materials in the same volume, and we obtained the frequencies of showers produced in these materials as the difference of the frequencies of the showers registered with and without the materials. In the second series (which is being performed) equal numbers of nuclei of two different elements are distributed in equal volumes. In this case the frequencies of the showers produced in the materials are proportional to the average cross sections of the respective nuclei.

In the present note we give the results of the first series, which consisted of experiments $A$ and $B$. The shower-producing materials were water and iron-filing located above the counter arrangement (equal masses in equal volumes). In experiment $A$ the upper counters of the telescopes had an area of 400 $cm^2$ each and the lower ones an area of 250 $cm^2$. In experiment $B$ all counters had an area of 600 $cm^2$ each. The resolving time of the circuit was $10^{-6}$ sec. The results are given in the table below.

TABLE I. Frequencies of penetrating showers in $h^{-1}$.

| | Exp. $A$ | Exp. $B$ |
|---|---|---|
| No material | $0.412 \pm 0.045$ | $1.06 \pm 0.08$ |
| $H_2O$ (57 g $cm^{-2}$) | $0.783 \pm 0.074$ | $2.07 \pm 0.12$ |
| Fe (57 g $cm^{-2}$) | $0.592 \pm 0.049$ | $1.37 \pm 0.14$ |
| $H_2O$ (120 g $cm^{-2}$) | | $2.02 \pm 0.11$ |
| Fe (120 g $cm^{-2}$) | | $1.34 \pm 0.12$ |

We see from these data that (a) the registered cross section per nucleon is larger in the case of water than in the case of iron, indicating that either the absorption coefficient of primaries or the constitution and multiplicity of the produced showers depends on the nuclear structure;[3] (b) with 57 g $cm^{-2}$ of water or iron we observed saturation; (c) the existence of a difference between the frequencies at saturation in the case of water and iron suggests that the constitution, multiplicity, or angular divergence of the produced showers are different in the two cases. (d) The intensity of the shower-producing radiation is reduced by a factor $\gtrsim 1/e$ in a thickness of 57 g $cm^{-2}$ in both $H_2O$ and Fe. We conclude that the lower limit of the cross sections of this radiation is in both cases of the order of the geometrical cross sections of the nuclei.[4]

We thank Prof. G. Wataghin for the suggestion of this problem and for his kind, constant help during the performance of the measurements.

[1] A preliminary account of this work was presented at the meeting on July 13 of the Academia Brasileira de Ciencias.
[2] G. Wataghin, Phys. Rev. **71**, 453 (1947).
[3] Similar conclusions can be drawn from a recent work of Cocconi and Greisen, Phys. Rev. **74**, 62 (1948).
[4] For further work on the production of penetrating showers we refer to: V. Regener, Phys. Rev. **64**, 250 (1943); W. Hasen, Phys. Rev. **64**, 257 (1943); L. Janossy and Rochester, Proc. Roy. Soc. **A183**, 183 (1944); L. Janossy and D. Broadbent, Proc. Roy. Soc. **A190**, 497 (1947); O. Sala and G. Wataghin, Phys. Rev. **70**, 430 (1946); E. George and A. Jason, Nature **161**, 248 (1948). We finally mention experiments on the production of penetrating showers in paraffin and lead made by Professor Clay (private communication to Professor Wataghin).

## The Beta-Spectrum of $S^{35}$

R. D. ALBERT AND C. S. WU
*Columbia University,* New York, New York*
August 19, 1948

RECENTLY Cook, Langer,[1] and Price[2] have published results on $S^{35}$ negatrons and both positrons and negatrons from $Cu^{64}$ which show an increase in number over that predicted by the Fermi theory at low energies. Because it is difficult to understand theoretically why such deviations should occur at low energy after the Coulomb correction has been made, an attempt was made to check these results with thinner sources. The Columbia University solenoid $\beta$-ray spectrometer[3,4] was used with eight different $S^{35}$ sources. These measurements all show straight-line Fermi plots for the upper half of the energy spectrum. Some show straight-line plots from the upper energy limit down to 16 kev, while others showed deviations from the straight line at much higher energies, similar to the curve given by Cook and Langer.[2] The solenoid spectrometer possesses advantages over the other type instruments in that it has a high geometric efficiency ($\sim$1 percent) and can use a large effective source area. This permits the use of extremely thin sources with as low as $\sim$1 microcurie of total activity and a resolution of 1.25 percent.

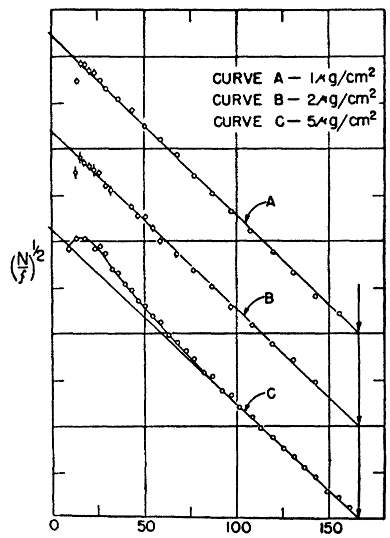


FIG. 1.

Figure 1, curves $A$ and $B$, show the results for two of the best sources prepared. Curve $C$ shows the results for a somewhat thicker source. These Fermi plots are corrected for the Coulomb effect, using the non-relativistic correction factor which agrees within $\sim$2 percent or better with the relativistic correction for $S^{35}$. The best straight line in each case was made to meet the axis at 166 kev; this value was obtained on each of several runs when the high energy region was investigated. The points of curves $A$ and $B$ do not deviate significantly from the straight-line plot above 16 kev. The drop at lower energies is probably instrumental and will be investigated further.

The counter windows consist of four thicknesses of collodion films prepared by spreading one drop of collodion solution (one part collodion, two parts amylacetate) over a pan of water in the usual manner. The total thickness is probably <30 micrograms/$cm^2$ and will transmit electrons down to 4 kev. The source backings were also collodion about 3 micrograms/$cm^2$. The sources were prepared by placing a drop of solution of carrier free $S^{35}$ (from Oak Ridge) on the backing and drying in such a manner that it spread over a suitable area. The deposit did not form a perfectly uniform layer, so that the maximum local thicknesses were hard to estimate. Assuming uniform spreading, the sources for Fig. 1A, B, C were