TABLE I. The observed microwave spectrum of formaldehyde.

Transition	Observed freq. (mc/sec.)	Calculated (mc/sec.)	Centrifugal distortion correction	Temperature* coefficient of intensity	Intensity
$25_{4,22}\rightarrow 25_{4,21}$	19595.23	19,593	−305	1/5	*m*
	20736.64			1/2	*w*
$9_{2,8}\rightarrow 9_{2,7}$	22,965.71	22,966	− 30	2	*s*
$17_{3,15}\rightarrow 17_{3,14}$	24,068.31	24,036	−147	1/3	*m*
$26_{4,23}\rightarrow 26_{4,22}$	26,358.70	26,390	−396	1/5	*w*

* Approximately, $I(-78°C)/I(25°C)$.

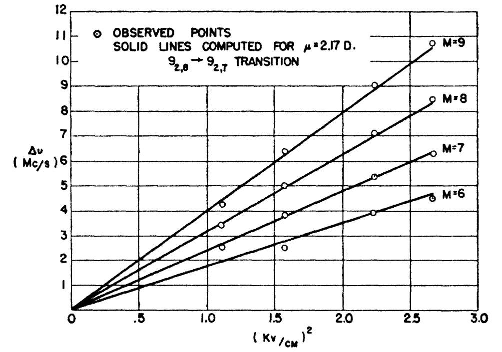

FIG. 1. Stark effect of formaldehyde absorption line at 22965.71 Mc/sec.

rections is rather large, since the results of calculation represent differences in large numbers, in which inadequacies in the assumptions made, or small discrepancies in the force constants, may be magnified. It is possible, for example, to change the correction to the $26_{4,23}\rightarrow 26_{4,22}$ transition by 10 megacycles simply by varying the HCO bending force constant within the limits of uncertainty quoted by Ebers and Nielsen. The magnitude of these corrections is due to the small moment of inertia about the twofold axis.

Four Stark components of the $9_{2,8}\rightarrow 9_{2,7}$ transition were resolved (see Fig. 1): their behavior as a function of frequency served to establish the identity of the line. The dipole moment in the ground vibrational state was calculated to be 2.17 ±0.02 Debye units, using asymmetric rotor theory.[7] As far as we know, the only previously reported value is[8] 2.27, measured at 420–520°K.

The identity of the line at 20,737 is not known: it cannot be identified with any pure rotational transition below $J=35$ on the basis of the present assignment. Nevertheless, one cannot interpret even three lines of the spectrum on the basis of any other choice of rotational constants. The present assignment predicts that the strong $3_{1,3}\rightarrow 3_{1,2}$ transition should fall at 29,058±50 megacycles.

Further work is planned on the identification of the 20,737 line, and on refinement of the centrifugal distortion corrections, with the eventual object of providing close estimates of the limits of accuracy of the present theory of the semirigid rotor. It is hoped the work will lead to an independent set of force constants, which may then be compared with those determined from vibrational spectra.

The values of the effective molecular parameters on which the calculated spectrum is based are $\kappa=-0.9612\pm 0.0001$ $\times(a-c)/2=1.2482\times 10^5\pm 0.006\times 10^5$ megacycles. These are in essential agreement with the values −0.9623 and 1.2391 10^5 calculated from the results of the ultraviolet spectrum.[9] The value of κ can be given rather precisely because the frequency of the high J transitions is extremely sensitive to the parameters; there is a corresponding large uncertainty in the value of $(a-c)/2$. Observation of the $3_{1,3}\rightarrow 3_{1,2}$ transition would suffice to determine the latter parameter with precision.

We wish to acknowledge the numerical calculations carried out by Miss Sally Thomas and Warren Thayer.

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The Emission of Protons from Boron and Argon on Bombardment with Po α-Particles

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BORON.—Earlier reports on the reaction $B^{10}(\alpha,p)C^{13}$ show that the compound nucleus $_7N^{14*}$ may decay with the emission of a proton leaving the final nucleus in the ground state or one of its excited states. The ground state transition ($Q=4.14$ Mev) escaped observation for a long time because of its feeble intensity. However, Brubaker and Pollard's[1] experiments gave a Q value of 4.7±0.5 Mev for the protons emitted from the ground state. Later this result was confirmed by other workers. Jentshke[2] and Merhaut[3] obtained the values 3.86 and 3.85 Mev, and Joliot and Zlotowski[4] 4.3 Mev for protons of the longest range group.

The Q valves corresponding to the protons which are emitted from the compound nucleus, leaving the final nucleus C^{13} in an excited state are 3.3, 0.5, 0.1, −0.78, and −1.86 Mev.

The present experiment, utilizing a cloud chamber was chiefly concerned with the investigation of the angular distribution of the protons arising from the various states. The polonium source, strength 5 mc, was deposited on a silver foil 2 mm×2 mm and the beam of α-particles was canalized through a slit arrangement before striking the target, the thickness of which was 0.8 cm air equivalent.

In the course of over 700 photographs 86 protons were obtained. Figure 1 shows the variation of the yield of protons with the incident α-particle energy. The curve does not indicate a well defined level. From considerations of the barrier

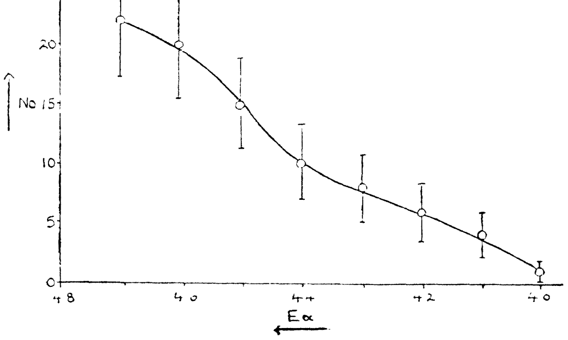

FIG. 1. The variation of the yield of protons with the incident α-particle energy.

TABLE I. Q values calculated from the energies of the emitted protons and incident α-particles.

No. of protons observed	Corresponding Q values in Mev
12	3.1
30	0.42
44	0.09

height of the B^{10} nucleus, it was estimated that the α-particle penetrated the nucleus through the top of the barrier and this could explain the absence of any peak in the curve.

The Q values calculated from the energies of the emitted protons and incident α-particles are given in Table I. These values are in close agreement with those reported by previous workers.

Owing to their feeble intensity there was no indication in this experiment of the longest range group of protons. No attempt was made to observe the protons from the still higher excited states because of their short ranges.

Miller, Duncanson, and May[5] reported a resonance level of the compound nucleus $7N^{14*}$ corresponding to the incident α-particle energy of 2.9 Mev but no evidence of this level was obtained in the present experiment.

It should be remembered that B^{10} is present to the extent of only 20 percent of the total, B^{11} constituting the remaining 80 percent. The reaction $B^{11}(\alpha,p)C^{14}$ gives a Q value of 0.88 Mev for the longest range group of protons. On comparison with Table I it may be seen that the protons corresponding to the Q value 3.1 Mev were from the reaction $B^{10}(\alpha,p)C^{13}$. In the remaining two groups (Q values 0.42 and 0.09 Mev) it is likely that B^{11} may also have contributed to the total yield, in which case the protons emitted came from such transitions as left the final nucleus C^{14} in the excited state. In the reaction $B^{11}(\alpha,p)C^{14}$ Pollard[6] did not observe any protons from the excited states, but only the long range group attributed to the ground state transition.

The angular distribution of the protons of Q values 0.42 and 0.09 Mev have been plotted (Fig. 2). The abscissa, θ, is in the C.M. system. These distributions appear to have broad maximums between 30°–65° for $Q=0.09$ Mev and between 45°–65° for $Q=0.42$ Mev, but it is more reasonable to assume the distributions in both cases to be isotropic within the limits of statistical fluctuation. Also the distribution for $Q=3.1$ Mev (not shown in Fig. 2) indicates no definite maximum in any direction. It should be noted that only 12 protons were observed and therefore no definite conclusions can be drawn.

For the second and third excited states, however, as the distributions are isotropic it can be said that the angular momentum of the incident α-particle is $l=0$ and consequently only an S-wave is involved in this interaction.

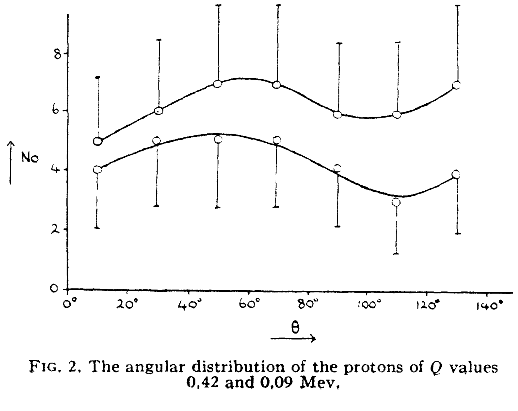

FIG. 2. The angular distribution of the protons of Q values 0.42 and 0.09 Mev.

Argon.—The investigation of Pollard and Brasefield[7] failed to detect any protons from the reaction $A^{40}(\alpha,p)Sc^{43}$. Using a cloud chamber and a strong α-particle source of $E\alpha=4.7$ Mev this reaction was studied in the present experiment.

In the course of 300 photographs, no protons were observed, which supports the findings of the previous workers. The isotropic masses of A^{40} and Sc^{43} are known.[8] It is also known that Sc^{43} is a positron emitter with a half-life of 4 hours. The Q value calculated from the mass-data is 3.71 Mev indicating that the reaction is energetically possible.

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On the Cosmic-Ray Stars

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BURSTS in thin-walled chambers show the same altitude dependence as stars in emulsions, so that both may be considered as being the same events. In fact, it was experimentally confirmed,[1] that most of such bursts were due to stars from the chamber wall. Meanwhile, Carmichael published his experimental data on bursts and analyzed them.[2] He thought that most of his "fragmentation" bursts were caused by single α-particles with rather high energy. But it is unlikely that such a high energy α-particle is frequently emitted in stars, so we reanalyzed his data and showed that these bursts could be explained by the ordinary star.[3]

The agents of these cosmic-ray stars are considered to be moderate energy nucleons (perhaps several hundred Mev), most of which are neutrons. These nucleons may be created in penetrating showers together with several mesotrons. We have calculated roughly the moderate energy nucleon intensity under the proton primary hypothesis.[4] If 1.6 such nucleons are produced in one penetrating shower in the average, we can obtain the correct intensity in the order of magnitude.

We can explain the most part of energy distribution curve of star particles according to the evaporation theory of nuclear physics.[5, 6] Figure 1 shows the experimental data of Perkins[7] and Weisskopf's distribution with the mean temperature of nuclei $\bar{T}=2.5$ Mev, which corresponds to the mean excitation energy $E_0\sim300$ Mev, and the barrier height $V=7$ Mev. Most of these stars seem to be originated form heavy nuclei in emulsion, such as Ag or Br, thus these $\bar{T}$ and V should certainly be reasonable. From this curve, we see that many more protons are emitted in high ($\gtrsim30$ Mev) as well as in low ($<V=7$ Mev) energy region than expected from the evaporation theory. As is well known, high energy protons are ejected from nuclei by a direct collision, not through the evaporation process. Thus, actually these protons must be added to evaporated ones. In order to explain the low energy protons, we are compelled to suppose either the nuclei are so enormously swelled out that barrier height decreases to a small fraction of its usual value,[6] or the protons penetrate the potential barrier by the tunnel effect. Since the compressibility of nuclear matter has a large value,[8] the former possibility will be too radical. Thus we may adopt the latter one.

The high energy nuclear reaction ($_{33}As^{75}+190$ Mev $_1D^2$) caused by Berkley cyclotron[9] throws the new light on our problem. From the yield of this reaction, we see that the number of emitted neutrons is about twice that of protons.