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.

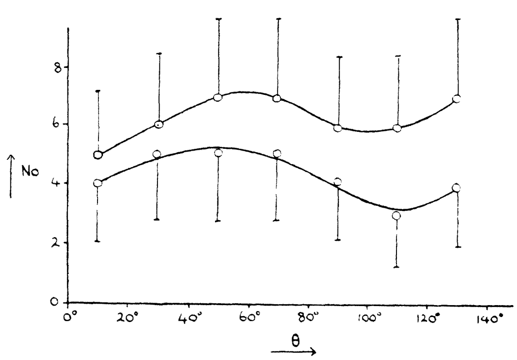

FIG. 2. The angular distribution of the protons of Q values 0.42 and 0.09 Mev.

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 $E_0\sim 300$ 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 ($\gtrsim 30$ 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.

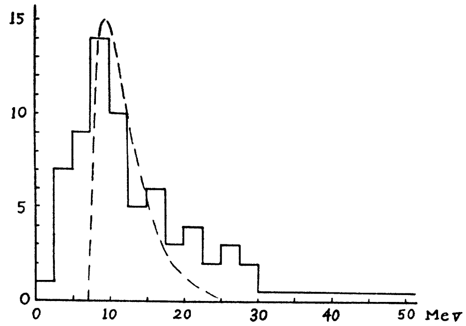

FIG. 1. Energy distribution of protons. The solid line represents the experimental data of Perkins. The dashed line is Weisskopf's distribution.

We may suppose the same circumstances will occur also in the cosmic-ray stars. This seems probable since the proton must go over the barrier. So after the evaporation process, the residual nucleus will be highly unstable, i.e., largely proton excessive. Under these circumstances it may be expected that a proton-decay will occur, analogous to the α-decay of heavy nuclei.

Assuming Geiger-Nuttal's law also to hold for the proton-decay, the lifetime of this new type of decay is estimated to be $10^{-15}-10^{-3}$ sec. for $A=100$ and proton energy $3-1.5$ Mev. This lifetime is much shorter than that of the β^{+}-decay. α- or γ-decay needs not to be considered because it does not improve the proton-excessive state. Finally, it is unlikely that the fission-like processes suggested by Bragge[6] occur in these nuclear states, because Bohr-Wheeler theory[10] shows that the threshold energy of fission has in our case a very large value ($\sim$40 Mev).

Thus we may conclude that the proton-decay predominates over other evaporation processes, and this will explain the appearance of low energy protons in stars. Also the cloud-chamber picture of Powell[11] seems to support the existence of this new type of decay; i.e., his picture Fig. 7a shows the heavy particle (proton) was emitted a few thousandths of a second after the evaporation process.

The detailed account will be published soon in *Progress of Theoretical Physics*. We should like to express our gratitude to Professor Tomonaga and Mr. Hayakawa for their kind interest taken in this work.

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Pressure Change of Resistance of Tellurium

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BRIDGMAN[1] has observed that the resistivity of tellurium decreases by a factor of more than 600 at a pressure of 30,000 kg/cm². He interprets this large change as a result of the tellurium becoming more metallic with increase in pressure. As shown particularly by work at Purdue University,[2] tellurium is a typical semiconductor with an energy gap between the filled band and the conduction band of about 0.38 ev.

TABLE I. Relative resistance and calculated energy gap in tellerium at a function of pressure.

I	II	III	IV	V
P		$\log_{10}R/R_0$		E_G
kg/cm²	23.5° from axis	86° from axis		ev
	30°C	30°C	75°C	
0	0	0	−0.311	0.29 (0.38
2500	−0.280	−0.384	−0.696	0.29 (0.33)
5000	−0.722	−0.739	−1.035	0.275 (0.29)
7500	−1.027	−1.066	−1.330	0.246
10,000	−1.302	−1.360	−1.590	0.214
12,500	−1.547	−1.622	−1.818	0.182
15,000	−1.761	−1.855	−2.020	0.154
17,500	−1.945	−2.063	−2.197	0.125
20,000	−2.110	−2.246	−2.353	0.100
22,500	−2.257	−2.408	−2.490	0.076
25,000	−2.386	−2.552	−2.610	0.054
27,500	−2.499	−2.679	−2.715	0.034
30,000	−2.599	−2.790	−2.806	0.015

The purpose of this note is to point out that the large change of resistivity with pressure is a result of a decrease in the energy gap, the gap becoming very small at 30,000 kg/cm². At a somewhat higher pressure (45,000 kg/cm²) Te undergoes a phase transition.[3] The high pressure modification may well be a true metallic phase.

Shown in the first four columns of Table I are Bridgman's measurements of the pressure change of resistance of a single crystal of tellurium. Measurements were made in two directions making angles of 23.5° and 86° to the axis of the crystal. In the 86° orientation measurements were made at 30°C and 75°C. Bridgman gives values of $\log_{10}R/R_0$, where R_0 is the resistance at 30°C at atmospheric pressure.

Very pure samples of Te are in the intrinsic conductivity range at room temperature, the resistance varying as

$$R=R_\infty \exp(E_G/2kT), \tag{1}$$

where T is the absolute temperature. The energy gap can be estimated from resistance measurements, R_1 and R_2, made at two different temperatures T_1 and T_2.

$$E_G=2k\log(R_1/R_2)/[1/T_1-1/T_2]. \tag{2}$$

Using Bridgman's data for the 86° orientation at the two temperatures, values of E_G in ev have been calculated from

$$E_G=0.93[\log_{10}R(30°\mathrm{C})-\log_{10}R(75°\mathrm{C})]. \tag{3}$$

The values are listed in column V of Table I and are plotted in Fig. 1. The sample is not entirely in the intrinsic range at pressures below 7500 kg/cm², at least at the lower temperature. An extrapolation of E_G from Bridgman's data obtained above 7500 kg/cm² to Miss Johnson's value of 0.38 ev at zero pressure is shown by the dotted line. Extrapolated values are given in parentheses in the table.

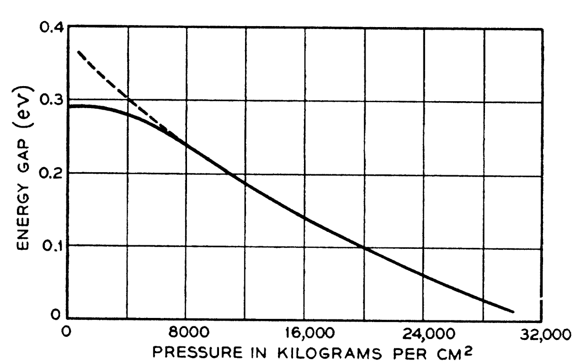

FIG. 1. Energy gap in tellurium as determined from variation of resistance with temperature at different pressures. Solid line; from Bridgman's data. Dotted line; extrapolation to $E_G=0.38$ ev at zero pressure.