# LETTERS TO THE EDITOR

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**Communications should not in general exceed 600 words in length.**

## On the Origin of Cosmic Radiation

In a recent letter[1] to this Journal, E. R. Sabato has criticized the "Cosmic cyclotron" process,[2] which I once suggested might account for the generation of cosmic radiation. The discrepancy between our opinions seems mainly to be due to the fact that Mr. Sabato has not decided—which is necessary—whether to treat the problem in a fixed coordinate system (as I have done) or in a system following the rotation. In the latter case he must take into account the polarization of the stars due to their axial rotation, which I have supposed to be small in a fixed system. If he does this he will no doubt arrive at the same result as I.

I think that when criticizing this old model Mr. Sabato ought to have mentioned that already two years ago I abandoned it in favor of a much more powerful (and simple) one, where the acceleration takes place mainly in the axial direction of the double star.[3] In this case the accelerated particles are hurled out directly into the surrounding space so that the objection (3)—the only correct one of Mr. Sabato's—does not apply to this case.

Since the discovery of cosmic radiation a multitude of hypotheses about its origin has been made. In general the idea is that such an unexpected and remarkable phenomenon must derive its origin from some very extraordinary processes. But before we regard the radiation as an indication of new natural laws, we ought to investigate if it is not possible to explain it in terms of the laws we know already. This is what I have tried to do, and the result is that classical electrodynamics applied to stellar motions and stellar magnetic fields can very well account for the generation of the cosmic rays. In spite of the fact that the theory has need of no assumptions more drastic than that the magnetic moments of some stars surpass that of our sun by some powers of ten, it is able to account for most of the experimental facts and is in conflict with none. It is clearly understood that it is not possible as yet to decide with certainty how the radiation is generated, but as long as there is no evidence against an explanation according to classical laws, there is little need to invent new laws, more or less arbitrary and fantastic.

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August 9, 1939.

[1] E. R. Sabato, Phys. Rev. **55**, 1272 (1939).
[2] E. R. Sabato, Zeits. f. Physik **105**, 319 (1937).
[3] E. R. Sabato, Zeits. f. Physik **107**, 579 (1937).

## Evidence for Incorrect Assignment of the Supposed $Si^{27}$ Radioactivity of 6.7-Minute Half-Life

It has been reported[1] that three different radioactive substances are produced by the bombardment of Mg with natural $\alpha$-particles. One of these, of 2.36-min. half-life, emits negative electrons, and was interpreted as $Al^{28}$, produced by the reaction $Mg^{25}$ $(\alpha, n)$. This assignment was subsequently proved correct when the same activity was produced from the reactions $Al^{27}$ $(d, p)$; $Al^{27}$ $(n, \gamma)$; $Si^{28}$ $(n, p)$ and $P^{31}$ $(n, \alpha)$. The second period of 11-min. half-life which was originally assigned to $Al^{29}$ is probably due to an impurity.[2] The third period (6.7 min.) was supposed to be a positron activity and was therefore assigned to $Si^{27}$, produced by a reaction $Mg^{24}$ $(\alpha, n)$. This assignment meets with several serious difficulties in the light of more recent evidence. (See below.) We have therefore repeated the experiment with the 16-Mev $\alpha$-particles furnished by the Purdue cyclotron. The result is that there is *no positron activity*, but only negative electrons. This proves that the previous assignment was incorrect and *that the 6.7-min. period is almost certainly* $Al^{29}$, formed by the reaction $Mg^{26}$ $(\alpha, p)$.

The arguments which led us to suspect the previous assignment as incorrect are the following.

(1) $Si^{27}$ should be produced in the reaction $Al^{27}$ $(p, n)$. Aluminum was bombarded with protons of more than 7 Mev in Rochester, but not a trace of the 6.7-min. activity was obtained although the energy of the protons must have been sufficient to produce the reaction.

(2) The reported positron energy (2.0 Mev) is much too low and the lifetime (6.7 min.) much too long to fall in line with the analogous nuclei which form a very regular sequence in both of these respects.[3] Extrapolating the experimental results obtained with lighter nuclei we should expect about 3.5-Mev positron energy and 4 seconds half-life for $Si^{27}$. Similar values are obtained from a theoretical estimate of the Coulomb energy.

(3) From the reported positron energy[4] of 2.0 Mev and the known reaction energy[5] of $Mg^{24}$ $(\alpha, p)$ $Al^{27}$, *viz.* $-1.6$ Mev, it follows that $Si^{27}$ can only be produced by $\alpha$-particles of more than 6.2 Mev, whereas Ellis and Henderson report it for 5.4 Mev.

(4) Bothe and Gentner[6] failed to find the activity when irradiating Si with 17-Mev $\gamma$-rays. 14.5 Mev should have been sufficient to produce the photoelectric effect, and there is no case known in which a well-established radioactive period could not be obtained by a $\gamma - n$ reaction.

When magnesium of commercial purity is bombarded with 16-Mev $\alpha$-particles both negative and positive electrons are observed. The latter show a half-life of 4.0 hours and are due to a calcium impurity. The sign of the charge was determined by magnetic resolution using a counter as a detector. With a source of very pure magnesium no positive electrons are observed by this method. The decay curve of the negative emission is similar to that for the total emission and shows the two periods of 2.3 and 6.4 min.

Photographs have been taken in a Wilson cloud chamber beginning 30 minutes after bombardment. At this time the intensity of the 2.3-min. activity is less than 1 percent of the total intensity. A series of 100 photographs taken after this time show that the electrons emitted by the 6.4-min. body are predominantly negative. However, several positive electrons were observed coming from the source. Out of a total of 748 tracks there were 22 positives. The positives were equally numerous at the beginning and end of the run, while the negative emission decreased by a factor of eight. They, therefore, seem to decay with a much longer period than 6.4 min. and may probably be due to a very small calcium impurity in the magnesium. Calculating from the known intensity of a pure calcium target, it turns out that one part in 5000 calcium impurity in the magnesium target would give rise to the observed number of positives.

The new assignment solves all the difficulties mentioned above. The actual $Si^{27}$ has been produced by Kuerti and Van Voorhis[7] since these experiments were begun. Kuerti and Van Voorhis find that $Si^{27}$ is produced by the reaction $Al^{27}$ $(p, n)$ $Si^{27}$ and has a half-life of 3.7 seconds which agrees with the expectation from analogous nuclei (paragraph 2 above).

Measurements of the curvature of 314 tracks of the negative electrons give a rough energy distribution and show that the upper limit of the spectrum is about 2.5 Mev. An absorption curve of the $\beta$-rays in aluminum gives an absorption coefficient $\mu/\rho=5.3$ and a range for the $\beta$-rays of 1.10 g/cm². These are consistent with the above value for the upper limit. The $\gamma$-rays, if any, associated with the 6.4-min. period are very weak; no ionization could be detected in the electroscope when the aluminum absorber had a thickness corresponding to 1.10 g/cm². With the mass of $Si^{29}$ given in reference 5, the mass of $Al^{29}$ is 28.9893 which fits in well with the masses of the neighboring elements.

We wish to thank Mr. D. R. Elliott of Purdue University for taking the cloud-chamber photographs.

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[1] C. D. Ellis and W. J. Henderson, Proc. Roy. Soc. **156**, 358 (1936).
[2] W. J. Henderson and R. L. Doran, Phys. Rev. **56**, 123 (1939).
[3] White, Delsasso, Fox and Creutz, Phys. Rev. **56**, 512 (1939).
[4] Alichanow, Alichanian and Dzelepow, Nature **133**, 950 (1934).
[5] M. S. Livingston and H. A. Bethe, Rev. Mod. Phys. **9**, 377 (1937).
[6] W. Bothe and W. Gentner, Zeits. f. Physik **106**, 236 (1937).
[7] G. Kuerti and S. N. Van Voorhis, Phys. Rev. **56**, 614 (1939).

## A Study of the Protons from Calcium under Deuteron Bombardment

Targets of CaO have been bombarded by 3.1-Mev deuterons from a cyclotron. Fig. 1 shows an absorption plot of the protons from both a thick and thin target, observation being made at right angles to the incident deuteron beam. Since protons from the reaction $O(dp)$ have a range of only 27 cm the groups at 66 cm and 96 cm corresponding to "$Q$" values of 4.51 Mev and 6.30 Mev must be attributed to $Ca(dp)$. The 66-cm group is considerably more intense

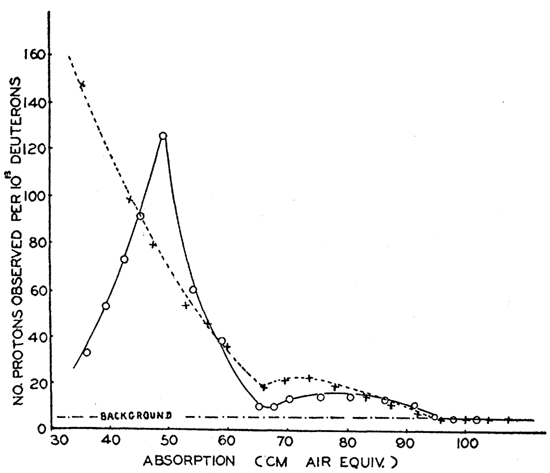


FIG. 1. Absorption plot of the protons from $CaO+H^2$. Circles refer to thin target yields; crosses to yields from a thick target. The abundant $O(dp)$ group at 27 cm is not included.

than the corresponding yield from $Sc(dp)$. Sc has only a single stable isotope. Since the element calcium is predominantly $Ca^{40}$ (96.76 percent), one can almost certainly attribute this group to the reaction

$$Ca^{40}+H^2\rightarrow Ca^{41}+H^1,$$

giving positive evidence for the actual formation of $Ca^{41}$. Walke[1] has searched unsuccessfully for the radioactivity resulting from such an isotope. Thus one can conclude that $Ca^{41}$ is either stable or else its half-life must be very short or very long. The former view seems untenable both from the result of Nier's[2] work which places an upper limit of $Ca^{41}/Ca^{40}=1/150{,}000$ and from the fact that adjoining stable isobars are extremely rare. Another possibility is that $Ca^{41}$ may decay to $K^{41}$ via $K$-electron capture. Such a possibility might explain why its activity was not observed, since the soft $x$-radiation may have been masked by the electrons from $Ca^{45}$.

I wish to thank Professor Ernest Pollard for his advice on this work.

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November 1, 1939.

[1] Harold Walke, Phys. Rev. **51**, 439 (1937).
[2] Alfred O. Nier, Phys. Rev. **53**, 282 (1938).