was wrapped in a 3-inch layer of cellulose padding and was heated electrically by storage batteries.

According to preflight plans, the instrument was to reach about 80,000 feet shortly after sundown and remain near that level until the following afternoon. Had this performance been realized, data from the Minnesota flight alone would have sufficed to establish the magnitude of the diurnal effect. Actually, the balloon altitude dropped rather rapidly after midnight and did not increase again at daybreak; consequently, it was necessary to compare the night counting rates at Minneapolis (geomag. lat. 55°N) with the day rates recorded at Swarthmore (geomag. lat. 52°N). The necessity of relying on the data from a single night flight is not regarded as a serious source of error, since variations in the data obtained from different instruments in numerous flights at Swarthmore and Ft. Churchill have been within the statistical uncertainties.

The latitude effect between Swarthmore and Minneapolis for this type of instrument is regarded as negligible in the light of previous measurements which have established that the daytime burst rates are the same at 52°N and 69°N at all altitudes up to 100,000 feet.

The altitudes and burst rates recorded during the night flight are plotted in Fig. 1. The dashed curve represents the counting rates averaged from four daytime flights at corresponding altitudes. The night counting rates are in excellent agreement with the day rates at all altitudes attained between sunset and sunrise. If a diurnal variation in the burst rate exists at all, its magnitude does not exceed the combined statistical and systematic uncertainties which are estimated as ±5 percent.

According to a previous analysis[1] of the daytime results, 37 percent of the bursts at 80,000 feet are caused by primary heavy nuclei of charge $Z \geq 8$ and the remainder by nuclear disintegrations occurring in the chamber walls. Excluding the possibility that the intensities of the heavy nuclei and of the star-producing radiation vary from night to day in opposite senses (an increase in one being partially compensated by a decrease in the other), it is concluded that the heavy nucleus intensity does not change by more than ±13 percent, nor the frequency of stars by more than ±9 percent from night to day.

Photographic emulsion results[3] have indicated that the diurnal variation in the frequency of stars at balloon altitudes is smaller than 5 percent. On the other hand, the available emulsion data concerning heavy nuclei[3–5] seem to show a nighttime drop in intensity of 50 to 70 percent below the daytime value for nuclei with $Z \geq 10$.

If the emulsion evidence is correct on both points, the ion chamber rates should have been 18 to 26 percent lower during the night, at 80,000 feet. Such an effect is not observed and indeed lies considerably outside the range of the systematic and statistical uncertainties in the present results.

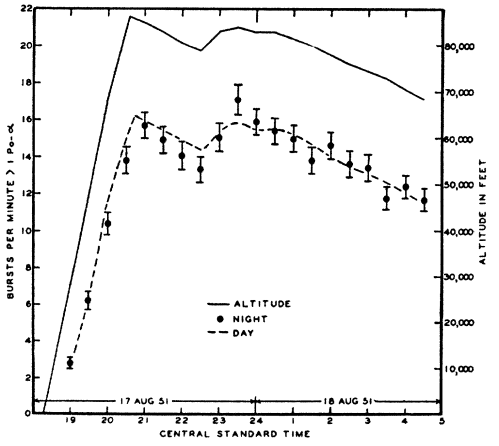

FIG. 1. Altitude *vs* time curve (solid line) for night flight at geomagnetic latitude 55°N and counting rates (solid circles) obtained with ionization chamber biased to record bursts ≥ 1 Po −α. Counting rates averaged from four daytime flights (dashed curve) at corresponding altitudes show no significant deviations from night rates.

We are grateful to Mr. A. T. Bauman for the arrangement and supervision of the balloon flight, and to the National Geographic Society for continued support.

* Assisted by the joint program of the ONR and AEC.

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Isolation of Radioactive C^{11} Formed by the Interaction of π^- Mesons on Oxygen and Nitrogen*

A. TURKEVICH AND J. B. NIDAY
Institute for Nuclear Studies, University of Chicago, Chicago, Illinois
(Received November 2, 1951)

PHOTOGRAPHIC plate studies[1] on nuclear stars produced by mesons imply that the residual nucleus left after the evaporation of neutrons and protons should often be radioactive. The 145-Mev π^- meson beam at the University of Chicago synchrocyclotron has been found to be sufficiently intense and free from other high energy particles to detect this expected production of radioactivity. The reactions leading to the formation of $C^{11}(\beta^+, 20.5\text{ m})$ that have been observed are

$$O^{16}(\pi^-; p, 4n)C^{11} \text{ and/or } O^{16}(\pi^-; 5n)N^{11} \xrightarrow{\beta^+} C^{11}$$

and

$$N^{14}(\pi^-; 3n)C^{11}.$$

The experimental arrangment is indicated in Fig. 1. Negative π-mesons are produced in the synchrocyclotron by the bombardment of an internal target with 450-Mev protons. The trajectories of the mesons produced in a forward direction are such as to bring them out of the vacuum chamber through a thin Lucite window. A channel through the six-foot iron shield of the cyclotron accepts only those mesons that have energies in the range of 140–150 Mev. After emerging from the shield they are bent through 45° by the analyzing magnet A. The intensity of the meson beam is measured by counting coincidences in two large liquid scintillation counters B and C. At least 98 percent of the coincidences disappear if the analyzing magnet field is changed appreciably from the correct value for 145-Mev π^- mesons.

The magnetic analysis establishes the sign and momentum of the charged particles. That the particles have the proper mass was established by a measurement of their range in aluminum and carbon[2] and by the measurement of their velocity using a Čerenkov detector.[3] Analysis of the range curve established the constitution of the beam as being 94±4 percent π^- mesons, 6±4 percent μ^- mesons, and <1 percent electrons.[2]

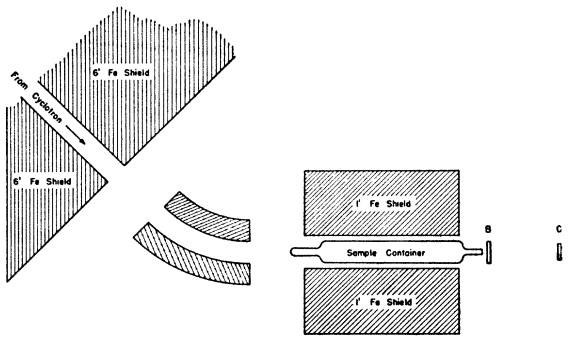

FIG. 1. Experimental arrangements for the irradiation of samples with π^- mesons.

TABLE I. Yields of C^{11} from π^- interaction with H_2O and NH_4NO_3 solutions.

Initial activity of C^{11} (counts/min)[a]	Saturation activity of C^{11} at 1-watt level (dis/min)[b]	Saturation activity of C^{11} at 1-watt level with analyzing magnet off (dis/min)	Net activity of C^{11} resulting from mesons (dis/min)	Meson intensity at 1-watt level (mesons/min)[c]	Yield of C^{11} per meson (percent)
Experiments with H_2O					
26	127	27	100	4500	2.3
46	159	5	155	9350	1.6
63	123	5	118	9250	1.3
53	162	14	148	6950	2.1
46	171	14	157	7100	2.2
				Average $=1.9\pm0.4$	
Experiments with 11M NH_4NO_3 solutions					
70	236	41	195	6500	3.0
58	296	41	255	5600	4.6
44	264	41	223	5650	4.0
57	268	9	259	9300	2.8
86	268	9	259	10000	2.6
57	459	36	423	9100	4.6
66	332	36	296	9450	3.1
34	355	36	318	8400	3.8
64	220	9	211	6750	3.1
123	285	9	276	6950	4.0
				Average $=3.6\pm0.6$	

[a] This represents the activity in counts/min (background subtracted) about ½ hr after a 40-min irradiation.
[b] Activity of C^{11} expressed in disintegrations per minute immediately after an infinite irradiation corrected for chemical yield. Customary irradiations were for about forty minutes at a level of 4 to 12 watts, and the usual chemical yield was 60 percent. The counting efficiency was 22 percent.
[c] This represents the meson intensity with the analyzing magnetic field set at the correct value for 145-Mev π^-. The meson intensity with the magnet off was less than two percent of this value.

The samples to be irradiated were placed between the analyzing magnet A and the first crystal counter B. They consisted of 4 liters of acidified water or saturated NH_4NO_3 solution (pH$\sim$3.5) in gas-tight glass vessels of about 4-inch diameter. The solutions also contained about 15 mg of CO_2 added as $NaHCO_3$, and in the last experiments, some CO. The path length for the mesons in the samples was in all cases appreciably greater than the range. About one-third of the mesons of this energy can be expected to undergo nuclear interactions before being slowed down; the remainder react after losing their kinetic energy.

After irradiation the radiocarbon in the chemical forms of CO and CO_2 was swept out of the sample with an inert gas, passed over hot CuO to oxidize the CO to CO_2, and then absorbed in 100 ml of dilute NaOH solution. Calcium carbonate was precipitated from the solution and the precipitate was mounted and counted with an end-window Geiger tube.[4] It was established that the radioactivity produced decayed with the expected half-life of 20.5 minutes and that the radiations had the proper absorption characteristics for C^{11}. Postponing the addition of the few milligrams of the carbon carrier until after the irradiation did not decrease the yield.

Table I gives the results of our experiments with and without the proper magnetic field in the analyzing magnet. The saturation activity in a given irradiation (disintegrations per minute of C^{11}) was calculated from a record of the heat developed in the meson-producing target (usual levels of operation were between four and twelve watts), from the chemical recovery of the C^{11} (as measured by the recovery of the added CO or CO_2 carrier), and from the efficiency of the Geiger counter for the C^{11} positrons. This latter was established by measuring the efficiency for a sample having a known number of disintegrations per minute and radiations similar to those of C^{11}.

In all the experiments listed, the yield of C^{11} with the magnet on is more than four times that with the magnet off. The yield with the magnet off is presumably due to stray fast neutrons. In the later experiments (using the extra iron shield, Fig. 1) the ratio is nine or greater. The results indicate that C^{11} is the product of about two percent of the interactions of the mesons with O^{16}. Since the experiments measure only that C^{11} that ends up in the chemical forms of CO or CO_2, the true yield may be a little higher.

The yield of C^{11} with the NH_4NO_3 solutions appears to be significantly higher. Although chemical effects in the NH_4NO_3 solution leading to a larger fraction of the radioactive carbon as CO and CO_2 cannot be completely ruled out, the results are explicable by postulating a fourfold higher yield of C^{11} from N^{14} than from O^{16}.

This work was made possible by the advice and equipment of Professor H. L. Anderson and by the cooperation of Mr. Ronald Martin.

* This research has been supported in part by a grant from the AEC.
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Electric Forming of n-Germanium Transistors Using Donor-Alloy Contacts

R. L. LONGINI
Electronics and Nuclear Physics Department, Westinghouse Research Laboratories, East Pittsburgh, Pennsylvania
(Received November 2, 1951)

STELMAK[1] shows that the presence of phosphorus (a donor material) in the collector probe is important for good collector formation in n-type germanium. He suggests that this is caused by the superficial diffusion of phosphorus into the germanium.

The process of diffusion into the germanium most probably involves the more rapid diffusion of lattice vacancies. These vacancies, in their random motion, permit diffusion of the impurity, but simultaneously themselves diffuse into the germanium. Furthermore, they must precede the impurity in this diffusion process. The maximum density of vacancies and impurities is, however, determined by the temperature for the former and the saturation solution for the latter (which may be temperature dependent). However, the density of impurity diffused into the germanium adjacent to the surface (the saturation density of impurity) is not dependent on the lattice-vacancy density, which merely determines the diffusion rate.[2]

It is proposed here that this combination of lattice vacancies and impurities can give rise to a $p-n$ hook[3] region near the probe, and that the process of electrical forming may consist of producing such a region.

Assuming a lattice-vacancy mechanism of diffusion of impurities, it follows that there will be a high density of impurities near the probe which drops off rapidly with distance from the probe. The density of vacancies, depending on the energy of the pulse, will be high at the probe but dropping off much less rapidly with distance than does the impurity content. For a proper pulse energy the vacancy density near the probe may be much less than the impurity density. Adjacent to the probe there is in all probability an n-type region because of high donor impurity density, whereas slightly farther out there is certainly an excess of vacancies and therefore a p-type region. Still farther out the bulk germanium n-type characteristic will predominate. Thus there will be a $p-n$ hook surrounding a properly formed collector.

Such a region will give rise to a current amplification (α) greater than the value of 2.5 which is expected[4] on the basis of mobility alone and which has been reported by a number of observers.

An examination of the possibilities in a p-type germanium transistor show that no equivalent hook (an $n-p$ hook) is possible, as again the vacancies must precede the impurity of the collector. An acceptor type impurity would merely make the region around the collector more p-type, as would the vacancies. Thus electrons would not be trapped as are holes in the p region of a $p-n$ hook.

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