sheets of fine grade emery paper, in such a way that all the activity was retained on the paper. The $p-n$ character of each new face was checked by means of a thermoelectric probe. The activity of the paper was measured in a fixed geometry with a scintillation counter. The weight of the sample was measured after each grinding. The results for two samples are shown in Fig. 1. Here are

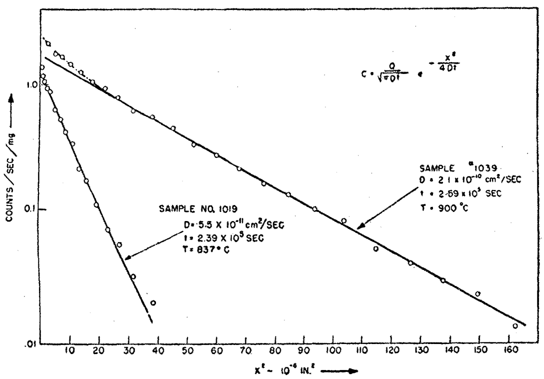

FIG. 1. Plot of log (counting rate) *vs* x^2 for the diffusion of radioactive antimony 124 into a germanium single crystal at two temperatures, 900°C and 837°C. The linearity of the plot on this chart is a test of the applicability of the "δ-function" solution of the diffusion equation.

plotted the counting rate per unit weight of material removed, *versus* the square of the distance from the original surface. This plot is chosen to check an important point. If the original surface layer could legitimately be considered to represent an infinitely sharp distribution (δ-function), the theoretical distribution of impurity should be given by the relation[2]

$$C=Q/(\pi Dt)^{-\frac{1}{2}}\exp(-x^2/4Dt),$$

where C is the concentration of diffusing impurity (atoms/cm^3), Q is the original surface density of impurity (atoms/cm^2), x is the distance in centimeters, t the time in seconds, and D the diffusion coefficient (cm^2/sec). Thus, the linearity of the curves on this plot is a check on the validity of the δ-function solution, and the slope of the lines obtained determines the diffusion coefficient. The good linearity obtained in all our tests shows that in spite of uncertainties that do exist regarding the actual initial conditions, including such effects as the formation of a liquid surface layer, 2-phase solid layers, effect of evaporation of the antimony, etc., all these effects either involve such a negligibly thin surface layer or are over within such a short time that they do not affect the diffusion in any important way.

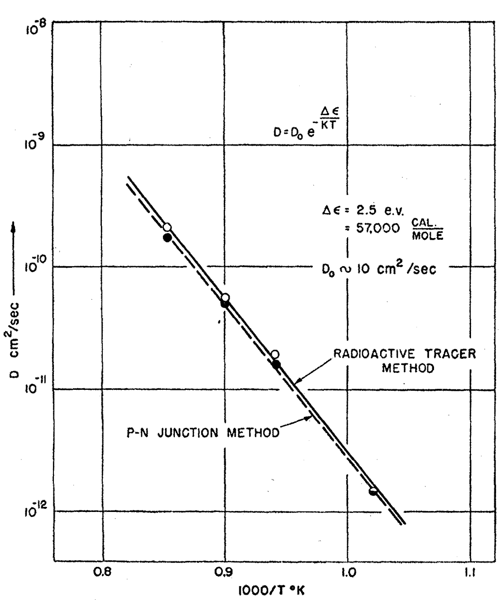

FIG. 2. Plot of the temperature variation of the diffusion coefficient for antimony in germanium determined by the $p-n$ junction method and by the radioactive tracer method. The good agreement observed justifies the use of the $p-n$ junction method for the measurement of diffusion in semiconductors.

Figure 2 shows the diffusion coefficients for antimony at various temperatures as measured by the $p-n$ junction method and by the radioactive tracer method. The results are seen to be in excellent agreement. The average difference between the values of D determined by the two methods is about 10 percent. The $p-n$ junction method gave uniformly lower values. The reason for this may be sought in the tendency of a thermoelectric probe to balance between p and n slightly on the n-type side, because of the tendency of surfaces to be p-type and because of the higher mobility of electrons than holes. However, a factor neglected in the radioactive tracer method was the absorption of the emitted β-rays in the germanium powder itself, and this may also affect the results slightly.

The activation energy determined from the slope was 2.5 ev, or 57,000 cal/mol. The value of D_0, the intercept of D on the $1/T=0$ axis, was about 10 cm^2/sec. A calculation of D_0 based upon the Langmuir-Dushman[3] diffusion equation gave a value $D_0 \sim 0.3$. The two values are in satisfactory agreement considering the uncertainty involved in the Langmuir-Dushman equation, the error in extrapolating for D_0, and the possibility that the activation energy is slightly dependent on temperature. Thus the diffusion is a true volume diffusion and does not involve the "short circuits" found by Nowick[4] to play a part in many diffusion studies.

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Unusual $\pi-\mu$ Decays in Photographic Emulsions

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THE search for unusual $\pi-\mu$ decays in photographic emulsions has been continued.[1] Electron sensitive G-5 plates have been exposed in the positive meson beams[2] of the University of Chicago cyclotron. A total of 10,686 $\pi-\mu$ decays have been observed in C-2 and G-5 plates where both the π- and μ-meson tracks stopped in the emulsion. Thirteen unusual events were found among the 10,674 normal $\pi-\mu$ decays. The data concerning the unusual $\pi-\mu$ decays are given in Table I.

Event 12 is interpreted as a decay in flight of a negative π-meson and has been described elsewhere.[3] The μ-meson in event 13 did not stop in the emulsion. The length of the μ-meson track is 975 microns. The number of gaps along the μ-meson track has been measured and compared with the gap density along a μ-meson track from a π-decay which stops within 100 microns of the μ-meson track of event 13. Using this method it was found that the residual range of the μ-meson track in event 13 is about 60 microns. The long range of the meson track of event 13 is most probably due to the decay in flight of the positive π-meson. The observed short ranges of the μ-meson tracks in events 8 through 11 are possibly due to the decay in flight in the backward direction of the π-mesons. Assuming that the short ranges of the μ-meson tracks in

TABLE I. Characteristics of unusual $\pi-\mu$ decays.

Event	Type of emulsion	Range of μ-meson track in microns	Energy of μ-meson in Mev	Measured angle between directions of π- and μ-meson tracks	Energy in Mev of π-meson assuming decay in flight
1[a]	C-2	120	1.6	73	5.0
2[a]	C-2	185	2.1	20	16.6
3[a]	G-5	290	2.7	59	6.6
4[a]	G-5	416	3.3	51	8.3
5[a]	G-5	430	3.35	26	15.4
6[a]	G-5	441	3.4	56	5.1
7[a]	G-5	470	3.35	28	15.4
8	C-2	258	2.5	93	1.7
9	C-2	260	2.5	113	0.7
10	G-5	444	3.4	160	0.03
11	G-5	476	3.5	117	0.09
12	C-2	828	4.8	10	0.05
13	G-5	1035	5.5	55	0.5

[a] Events which do not appear to be decays in flight of the π-mesons.

events 1 through 7 are due to the decay in flight of the π-mesons, the energy of the π-mesons at the time they decayed can be calculated from the directions of the π- and μ-mesons and the ranges of the μ-meson tracks. In events 1 through 7 the grain density near the ends of the π-meson tracks is clearly inconsistent with the assumption of decay in flight of the π-mesons. However, it cannot be entirely ruled out that the π-mesons were scattered through a large angle in the last one or two grains and subsequently decayed in flight in the backward direction. From a study of the large angle scatterings near the end of the π-meson tracks of normal $\pi-\mu$ decays, it was found that the probability of large angle scatterings is quite small, hence the probability that a π-meson would be scattered and subsequently decay in flight is extremely small ($\sim 10^{-5}$). For this reason it seems quite certain that the short ranges of the μ-meson tracks in events 1 through 7 are not due to the decay in flight of the π-mesons. A decay electron track is observed from the end of each of the μ-meson tracks which stopped in G-5 plates. A study of the grain density and the total energy of the δ-rays along the μ-meson tracks indicate that the μ-mesons were ejected with a lower velocity than in normal $\pi-\mu$ decays. The range distribution of μ-mesons from π-meson decays in C-2 plates has been studied. From this study it is concluded that the events where the ranges of the μ-meson tracks are less than 480 microns cannot be due to straggling. Correcting for the increased probability that short μ-meson tracks will end in the emulsion, the ratio of unusual $\pi-\mu$ decays (range of the μ-meson track <480 microns) to normal $\pi-\mu$ decays is then $2.8\pm1.2\times10^{-4}$ if the events which can be explained by decay in flight are not included. A micro-projection drawing of event 4 is shown in Fig. 1.

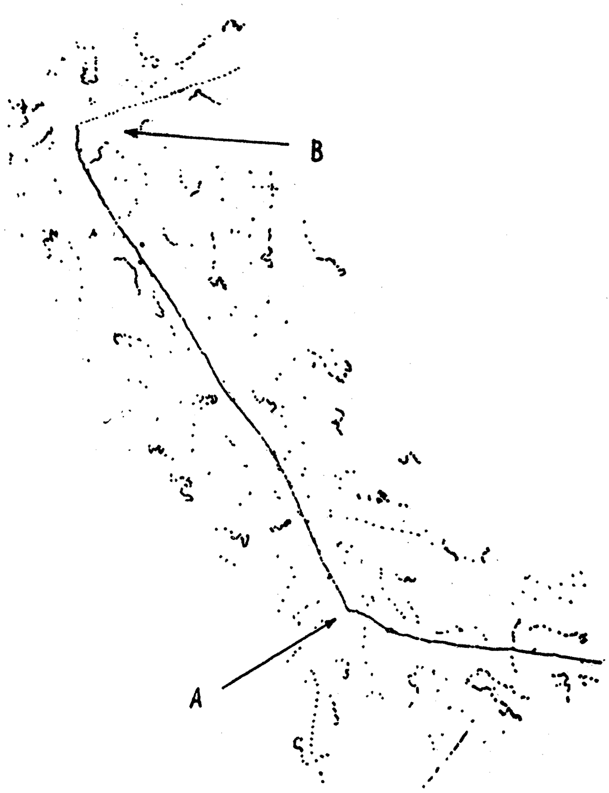

FIG. 1. An unusual $\pi-\mu-e$ decay which is listed as event 4. The $\pi-\mu$ junction is indicated by arrow A and the $\mu-e$ junction by arrow B. The range of the μ-meson track is 416 microns. The normal range of the μ-meson tracks from decays is about 600 microns.

Short μ-meson tracks from π-meson decays have also been found by Powell,[4] Smith,[5] and Seifert, Bramson, and Havens.[6] A theoretical explanation of the occurrence of unusual $\pi-\mu$ decays in terms of soft photon emission has been given independently by Primakoff,[7] Eguchi,[8] and Nakano, Nishimura, and Yamaguchi.[9] The percentage of unusual $\pi-\mu$ decays and the energy distribution of the μ-mesons appear to be in general agreement with the theoretical predictions based on a soft photon emission accompanying the charge acceleration of the μ-mesons from the π-meson decays.

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Polarization of D-D Neutrons*

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AN attempt has been made to detect the polarization of the fast neutrons of the D-D reaction at very low bombarding energies. Various descriptions[1,2] of the interactions in the D-D reaction result in the possibility of a polarization of the D-D neutrons. A method proposed by Schwinger[3] to detect polarization of fast neutrons was used in this experiment. The experimental arrangement is shown in Fig. 1.

Following Schwinger's notation, $P_1(\theta_1)$ is the fraction polarized of neutrons emerging from source at angle θ_1 and $P_2(\theta_2)$ is the fraction of the neutrons polarized by the Pb scatterer emerging from the scatterer at angle θ_2. The ratio of the neutron intensities, I, at positions 1 and 2 is given by

$$R=\frac{I_2}{I_1}=\frac{1+P_1(\theta_1)P_2(\theta_2)}{1-P_1(\theta_1)P_2(\theta_2)}.$$