TABLE II. Bombardment data for *P*-type samples bombarded successively at −78°C and 55°C.

Sample	$n_h^0(-78°C)$	$dn_h/d(nvt)_{fast}$ at −78°C	at 55°C
1	4.01×10^{16}	−0.99	0.20
2	4.69×10^{16}	−1.12	0.396
3	4.86×10^{16}	−1.03	+
4	7.23×10^{16}	−1.10	+

−78°C and positive at 55°C in agreement with theory. Thus the James-Lehman model is qualitatively verified by these experiments.

An idea of the magnitude of ζ_{limit} for Ge may be obtained from Eq. (1) and the experimental data. The values of n_h^0 for sample 1 of Table I and sample 4 of Table II may be used to bracket $(n_h)_{limit}$. At 55°C 7.23×10^{16} cm^{-3} $<(n_h)_{limit}<7.02\times10^{17}$ cm^{-3}, and from Eq. (1) it can be shown that 0.168 ev $>\zeta_{limit}>$ 0.105 ev. Further experiments designed to determine ζ_{limit} more exactly and to test the model more rigorously are underway.

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[4] The samples used in these investigations were kindly prepared and furnished by Miss Louise Roth, Purdue University.

Measurement of the Cross Section for the Reaction $T+T\rightarrow He^4+2n+11.4$ Mev*

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(Received October 1, 1951)

A MEASUREMENT of the cross section for the reaction

$$T+T\rightarrow He^4+2n+11.4 \text{ Mev}$$

has been made using the 2.5-Mev Los Alamos electrostatic generator. An analyzed beam of tritons was passed through a 1/20-mil Ni foil into a thin gaseous tritium target.[1] The triton energy was varied from 40 kev to 2.22 Mev. The average triton energy in the center of the target was calculated by taking into account the energy loss in the Ni foil and the target gas. At triton energies below 100 kev the straggling is quite large, and the results at this low energy are presented only to show the general shape of the cross section. The neutrons produced from the reaction were detected with a "long counter."[2]

The neutron spectrum from the reaction has been examined in some detail,[3,4] and except for the presence of two rather broad peaks at 8.1 and 10.4 Mev, there seem to be equal numbers of neutrons per energy interval up to 11 Mev, with few neutrons having an energy greater than 11.5 Mev. The neutron detector had a response which was essentially flat up to 5 Mev and had an efficiency at 14 Mev which was 67 percent of that at 5 Mev. However, since the neutron spectrum from the T+T reaction is similar to that obtained from the Ra−Be source which was used to calibrate the detector, no counter efficiency correction has been applied in computing the cross section.

The main difficulties encountered in this experiment were caused by the presence of background neutrons produced by the interaction of tritons with various materials present on defining slits, etc. It was found that at energies above 1 Mev a large number of neutrons were produced from the action of tritons on aluminum. For this reason 1/20-mil Ni foils instead of aluminum foils were used as windows between the acceleration tube and the target chamber. Backgrounds were taken with He^4 replacing the tritium in the target. Above 1.2 Mev the background neutron yield increased more rapidly than did the (T+T) reaction, and as a consequence the errors of the measurement increased markedly. Since the arc gas contained a high percentage of H_2, the triton beam of highest energy whose composition was known (there was no deuterium in the system) was the HT^+ beam. However, in order to reach higher energies it was necessary to use a mass 3 beam. The mass 3 beam, however, was composed of singly ionized triatomic hydrogen molecules as well as monatomic tritium ions. To correct the beam current measurement for the presence of the triatomic hydrogen molecules the ratio of the yield between singly ionized mass 4 and mass 3 beams was obtained for several energies between 1150 and 1350 kev, and the factor was applied to the data taken with the singly ionized mass 3 beam above 1.35 Mev. The ratio which was obtained was checked at the end of each run, and the beam composition was found to remain quite constant.

Figure 1 gives the differential cross section in millibarns per steradian at 0° for the reaction $T+T\rightarrow He^4+2n+11.4$ Mev as determined by detecting the neutrons. If one wishes to obtain the number of neutrons produced, since there are two neutrons pro-

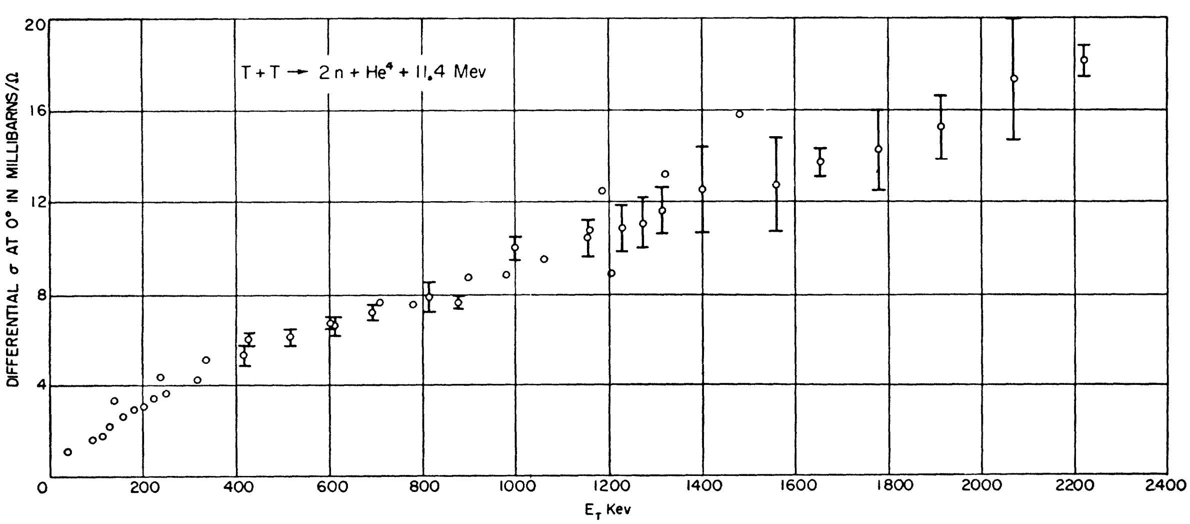

FIG. 1. Differential cross section in millibarns per steradian as determined with the neutron detector at 0° for the reaction $T+T\rightarrow He^4+2n+11.4$ Mev.

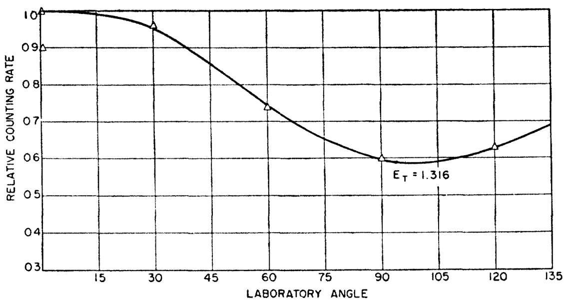

FIG. 2. Neutron angular distribution taken at a triton energy of 1.316 Mev.

duced per reaction, one multiplies the ordinate by two. The deviations indicated in Fig. 1 were obtained from the consistency of at least three sets of data, each of which was obtained under different operating conditions. The statistical error expected at any point should be less than 4 percent, and other errors are believed to be correspondingly small. The larger deviations are caused primarily by the large variable background.

A typical neutron angular distribution, taken at a triton energy of 1.316 Mev, is shown in Fig. 2. A similar shape was found for the entire energy range covered.

If the ordinate of Fig. 1 is multiplied by 10, one obtains a value for the total cross section of the reaction as a function of energy. The purity of the tritium used in the target was determined by means of mass spectrometric analysis, and the arc gas was analyzed for deuterium in the same manner. It was found that deuterium was present in quantities less than 0.02 percent as compared to the other hydrogen isotopes. The authors wish to thank Mr. Robert Potter and Dr. John Mosely for their assistance in the purity determinations.

* Work performed under the auspices of the AEC.

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The Anomalous Magnetoresistance of Bismuth at Low Temperatures

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(Received September 26, 1951)

AN investigation of the magnetoresistance of bismuth at liquid helium temperatures was first carried out by de Haas, Blom, and Schubnikow,[1] who used single crystals of very high purity in fields ranging up to 22,000 gauss. These authors showed that for certain orientations of the crystal the resistance was not a simple function of the field, but that rather large anomalies appeared at fields of about 9000 gauss and 18,000 gauss. This anomalous behavior has been associated[2] with the susceptibility oscillations of the de Haas–van Alphen effect.[3]

We have extended the measurements of magnetoresistance of bismuth crystals to fields in excess of 60,000 gauss, supplied by a Bitter-type solenoid.[4] The specimens used in this investigation were monocrystalline cylindrical rods about 2 mm in diameter and 2-to-3 cm long prepared by the methods of Kapitza[5] and Schubnikow[6] from "spectroscopically pure" (Johnson and Matthey) bismuth. To improve the purity of the metal, each crystal was regrown several times using one end as a seed. After each growing the end of the specimen last to solidify was broken off and discarded. The angle between the trigonal axis of a specimen and the geometrical axis is given in Table I.

TABLE I. Characteristics of crystal specimens used. θ is the angle between the trigonal axis of the crystal and the geometrical axis of the specimen. Resistance ratio of the specimen of de Haas *et al.* (No. 4) is given for reference.

Crystal no.	θ	$R_{4.2°K}/R_{0°C}$
1	8°	3.0×10^{-2}
2	19°	5.5×10^{-3}
3	9°	4.8×10^{-3}
...	...	...
4	0.5°	3.0×10^{-3}

The rods were mounted transverse to the magnetic field. By means of a gear mechanism the specimen could be rotated about its own axis, thus allowing measurements to be made of the resistance as a function of the angle between the magnetic field and one of the binary axes. At fields below about 3000 gauss the resistance was a simple function of this angle, giving a maximum for the field perpendicular to a binary axis ($\phi=0°$), and minima for the field parallel to the adjacent binary axes ($\phi=\pm30°$). This is similar to the behavior at higher temperatures. At higher fields, the resistance became a very complex function of the angle ϕ, with several maxima between $\phi=\pm30°$. The most unusual behavior appeared in the vicinity of $\phi=0°$.

A plot of the resistance *vs* magnetic field at 4.2°K and $\phi=0°$ for three specimens is shown in Fig. 1. The de Haas data (with the ordinate drawn half scale) are given by the dashed line. Taking the resistance ratio $R_{4.2°K}/R_{0°C}$ to be a measure of the degree of purity and freedom from strain in the specimens,[7] it is evident from examination of Table I and Fig. 1 that purity has a strong influence on the magnitude of the magnetoresistive effect, but appears to have no great effect on the values of field intensity at which the anomalies appear. If this be the case, the difference between the results of de Haas *et al.*, and those reported here, may reside in the size of the specimens used. The previous work was done using a crystal of square cross section, 7 mm on a side and 22 mm in length, while the crystals used in these experiments were not more than 2 mm in diameter and between 2-and-3 cm long.

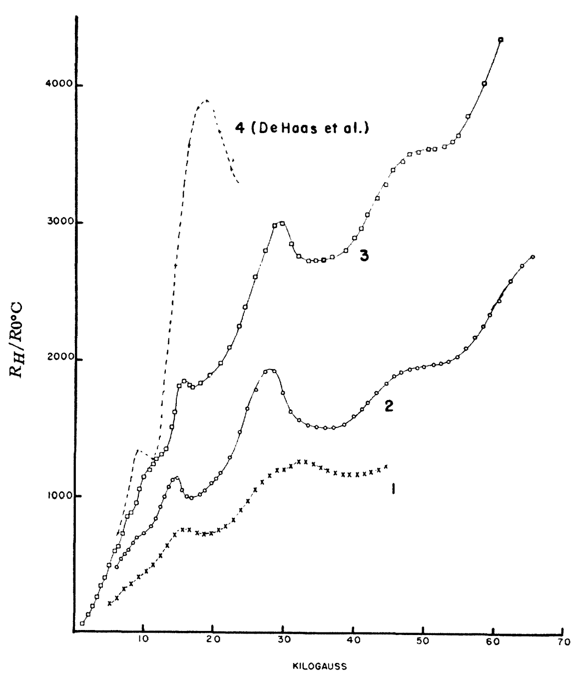

FIG. 1. Magnetoresistance of several bismuth crystals in transverse fields at 4.2°K. $\phi=0°$, i.e., the magnetic field is perpendicular to one of the binary axes. The values of θ (the angle between the trigonal axis and the geometrical axis of the specimen) are given in Table I. Dotted curve represents the data of de Haas, Blom, and Schubnikow (reference 1), with the ordinate drawn half scale.