discrepancy factor $\Sigma||F_{\text{obs}}|-|F_{\text{calc}}||/\Sigma|F_{\text{obs}}|$ was 9.4 percent for the initial parameters and 5.9 percent for the final ones.

The results show conclusively that the arrangement of hydrogen atoms is ordered. The hydrogen atoms are situated 1.07A from oxygen atoms O_1, nearly along the hydrogen bonds. The length of the phosphorus-to-hydroxyl-oxygen link is 1.56A, while that of the other P–O link is slightly shorter, 1.53A. The length of the hydrogen bond, $O-H\cdots O$, is 2.50A. All of these distances are close to those existing in the tetragonal room-temperature modification, where the hydrogen atoms are probably disordered.[6]

Some of the parameters for oxygen derived here differ by small but possibly significant amounts from those given by x-ray diffraction.[2] Should these differences prove to be real, they may indicate that some of the atomic nuclei are displaced away from the centroids of the extranuclear-electron clouds. Such displacements might play a significant role in the ferroelectric behavior of this crystal.

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[*] Work performed at the Oak Ridge National Laboratory under the auspices of the U. S. Atomic Energy Commission.

[†] Research participant, Oak Ridge Institute of Nuclear Studies, summer of 1952.

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[4] Because of overlapping peaks, the (*hhl*) projection cannot yield all the atomic parameters independently. Throughout this treatment, the assumption was made that $x+y$ for O_1 is equal to $y-x$ for O_2, in agreement with the x-ray result (reference 2) and that $x+y$ for H has the same value. The latter assumption places H in a plane parallel to c passing through the hydrogen-bonded oxygen atoms.

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Theory of the Galvanomagnetic Effects in *n*-Germanium

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SEITZ[1] has computed the galvanomagnetic constants of germanium, assuming spherical energy surfaces in momentum space and a relaxation time with cubic symmetry. His results, however, do not fit the published experimental data.[2,3] Shockley[4] has suggested that the energy surfaces may be degenerate, but has not presented any explicit calculations.

We have carried through calculations for *n*-type germanium, based on the following assumptions: (1) The relaxation time is given by $\tau=L/\sqrt{E}$, where E is the energy and L a constant. (2) The energy as function of momentum (**P**) has a number of minima; electrons near each of these minima contribute to the conductivity; and the energy surfaces, near the minima, can be approximated by quadratic functions of **P**.

For brevity, we shall refer to these quadratic functions as ellipsoids. The ellipsoids must be arranged in the Brillouin zone so as to obtain the cubical symmetry of the germanium crystal. We have considered the two simplest models which fulfill this requirement: (a) three rotational ellipsoids, with rotational axes perpendicular to each other; (b) four rotational ellipsoids, with their rotational axes along the body diagonals of a cube.

Model (a) may result when the energy minima are situated at the center of the small faces, and model (b), when they are situated on the large faces, of the first Brillouin zone of the face-centered cubic lattice.[5]

Our calculations are based on the series expansion of the distribution function [e.g., Wilson,[6] Eq. (8.551.3)]. This equation is written in tensor form; terms in H^3 and higher are neglected. On our assumptions, the integrals giving the current [Wilson, Eq. (8.551.4)] can then be computed for each ellipsoid. The total current I is obtained by summing over all the ellipsoids. By inversion, we obtain an expression for E, as function of I and H, in which the coefficients are the galvanomagnetic constants. It was found that the experimental results for *n*-germanium cannot be explained on the basis of model (*a*). Calculations based on this model result in zero longitudinal magnetoresistance effect in the (100) direction. However, a good fit can be obtained, using model (*b*). The only parameter appearing in the results is the ratio K of the effective masses, $K>1$ corresponding to prolate energy ellipsoids and $0<K<1$ to oblate. The results are:

$$R_H=(3\pi/8)[3K(K+2)/(2K+1)^2](1/nec),$$

$$L_{(100)}=(8/3\pi)R_H^2\sigma^2(2K+1)(K-1)^2/K(K+2)^2,$$

$$T_{(100)(010)}=(1/3\pi)R_H^2\sigma^2[K^2(16-3\pi)+K(16-6\pi)+4]/K(K+2),$$

$$L_{(110)}=(1/2)L_{(100)},$$

$$T_{(110)(1\bar{1}0)}=(1/2)L_{(100)}+T_{(100)(010)},$$

$$T_{(110)(001)}=T_{(100)(010)},$$

where the Hall coefficient is denoted by R_H; the conductivity by σ; the number of electrons in the conduction band by n; the longitudinal magnetoresistance coefficient by $L_{(ikl)}$ (the indices giving the crystallographic direction of I and H); and the transverse coefficient by $T_{(ikl)(mnp)}$ (the first set of indices giving the direction of I, and the second set, the direction of H).

TABLE I. Comparison of theoretical and experimental magnetoresistance coefficients (in gauss^{-2}).

Coefficient	Calc[a]	Exp[b]
$L_{(100)}$	$1.91\cdot10^{-9}$	$1.92\cdot10^{-9}$
$T_{(100)(010)}$	0.91	0.90
$T_{(110)(001)}$	0.91	1.03
$T_{(110)(1\bar{1}0)}$	1.86	1.68
$L_{(110)}$	0.95	0.99

[a] Calculated for $K=20$; values for R_H and σ as found by Pearson and Suhl (reference 3) for their *n*-germanium sample at 300°K.

[b] Measurements of Pearson and Suhl on above sample.

Table I shows that the values obtained from these equations for $K=20$ compare closely with the measurements of Pearson and Suhl.[3]

In the equation for R_H, the numerical coefficient gives the ratio of Hall- to drift-mobility. Inserting $K=20$, the value of $0.79(3\pi/8)$ is obtained for this ratio.

Calculations were also made for the sample measured by Pearson and Suhl at 77°K. Agreement was somewhat less satisfactory. However, a better fit can be obtained by taking impurity scattering into account.

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Origin of Retrograde Motion of Arc Cathode Spots

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MINORSKY discovered that if a transverse magnetic field acts on the cathode region of a mercury arc, under certain conditions the cathode spot will move contrary to Ampere's rule.[1] The positive column necessarily remains attached to the spot but is always deflected in the Ampere direction. If the pressure is sufficiently low, the motion is retrograde, but changes to the Ampere direction if the pressure exceeds a critical value which is the greater the lower the current and the stronger the magnetic field. Hitherto no explanation of this effect has carried great conviction.[2] We believe that it can be understood as a classical electrodynamic problem.

Using a tube similar to Gallagher's, at a vapor pressure of ≈20 mm Hg and a current of ≈10 amp, we observed for moderate magnetic fields that the spot moved in the Ampere direction and that the constricted positive column immediately above the spot was only slightly deflected. However, in a large field, this part of the column was deflected up to 90° and the movement of the spot reversed.

In the cathode fall region, probably within 10^{-3} cm from the cathode,[3] the electric field is high, but in the constricted column above it, the electric field is very much smaller. An applied magnetic field can therefore cause considerable deflection of the constricted column only and little deflection of the fall region so that the column is sharply curved at the junction. We believe that at the junction of the fall region and the constricted column, the vapor from the spot is excited and ionized. The direction of the resultant electromagnetic force in this region thus determines the direction in which the arc moves, since the location of the spot on the cathode depends on the position of this region in space.

The resultant horizontal force in this region consists of two components. One, proportional to iH, is in the Ampere direction; the other is of order i^2/ρ in the retrograde direction, because of the self-magnetic field of the curved current path consisting of the bent column and the deflected lines of current in the liquid (illustrated by the observed electromagnetic pumping). Here i is the current, H the applied magnetic field, and ρ an equivalent radius of curvature at the junction of the fall region and the constricted column. When $H=10^3$ oersted and $i=10$ amp, the two forces will be equal if $\rho\approx 10^{-3}$ cm, which is comparable with the dimensions of the fall region.

If H is increased ρ decreases and the retrograde component is the larger one, and vice versa. If the vapor pressure is increased, the column is constricted along a greater length and it becomes "stiffer" in the given magnetic field. Hence ρ increases and the motion becomes "Ampere." All this agrees with observations.

Retrograde motion is observed for both metal and carbon cathodes provided there is a cathode spot of high current density. If the entire cathode is heated to a temperature at which thermionic emission occurs, the current densities are too low for the self-magnetic field to be significant and retrograde motion ceases.[4]

This letter is published by permission of the Director of the Electrical Research Association, the sponsor of this work. A more detailed account will follow shortly.

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Short-Lived Metastable States of W^{182}†

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The β decay of Ta^{182} (111 days) is followed by the emission of many gamma rays. The continuous β spectrum, the γ-ray spectrum, and the spectrum of internal conversion electrons have been investigated[1] by several workers. In spite of the fact that the energies of the most prominent gamma rays are known to a high degree of precision,[2] no complete decay scheme has as yet been formulated. An early search for short-lived nuclear isomers by other workers[3] has yielded negative results with an upper limit of 5×10^{-9} sec for the lifetime of any excited state in W^{182} formed by the β decay of Ta^{182}.

The lifetimes of two short-lived metastable states of W^{182} have now been measured by fast-coincidence techniques. The coincidence arrangement used in these measurements is similar to those described by other workers.[4–6] *Trans*-stilbene phosphors on RCA 5819 photomultipliers were used as electron and gamma-ray detectors. Delays were introduced into the appropriate channel by inserting lengths of RG7/U cable. The resolving time used in these measurements was $2\tau\simeq3\times10^{-9}$ sec. Pulse-height selection was imposed upon the pulse distribution from each counter. The outputs of the fast-coincidence circuit and the two pulse-height selectors were mixed in a slow triple-coincidence arrangement in the usual way. As emphasized previously,[4] the precaution of pulse-height selection is necessary to minimize changes in the resolution curve of the coincidence circuit due to differences in input pulse size. The variation in pulse size allowed by the pulse-height selector channel widths was about 12 percent. Prompt-coincidence resolution curves were taken with identical pulse distributions within the limits allowed by the channel widths of the pulse-height selectors. The two lifetimes were found in the following ways:

(1) A typical time distribution of coincidences taken between a portion of the continuous β spectrum and a portion of the Compton distribution arising from hard γ rays is shown in Fig. 1 as $F(t)$.

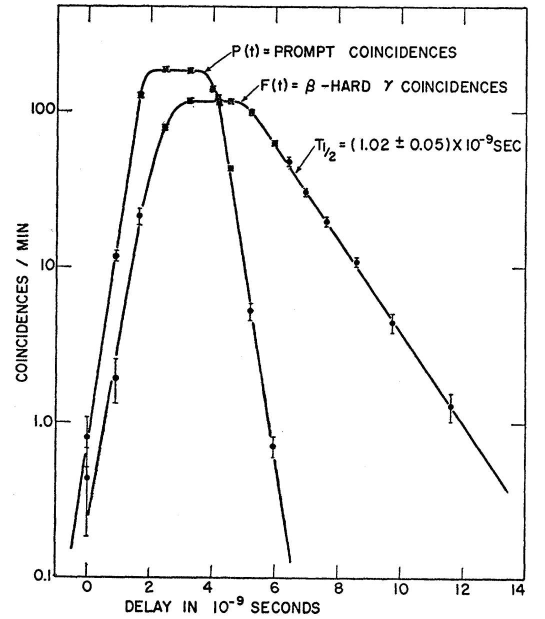

FIG. 1. Time distribution of β—hard γ-ray coincidences. $F(t)$ and $P(t)$ are normalized to the same included area. $F(t)$ has been derived from the experimentally observed $F(t)$ by subtraction of a 17-percent prompt-coincidence component. Narrow window energy selection imposed upon both counters.

$P(t)$ is the prompt resolution curve normalized to the same included area. The $F(t)$ shown is not precisely the experimentally obtained $F(t)$. We shall return to this point later. A centroid analysis[7,8] of $F(t)$ and $P(t)$ leads to the following value for the lifetime of the delayed state: $T_{\frac{1}{2}}=0.98\pm0.07\times10^{-9}$ sec. The lifetime obtained from the exponential tail of $F(t)$ [several runs] is $1.05\pm0.07\times10^{-9}$ sec. We adopt $1.02\pm0.05\times10^{-9}$ sec as the half-life.

The $F(t)$ shown in Fig. 1 was obtained from the experimental $F(t)$ by subtracting a curve of the form of $P(t)$. The subtracted area was 17 percent of the original area. This subtraction was necessary because of an $\sim$17 percent prompt-coincidence component in the Ta β—hard γ delay curve. This prompt component may arise because not all of the hard γ rays following β emission by Ta^{182} are delayed. The presence of low-intensity γ rays of intermediate energy following a different β branch may also contribute to this prompt-coincidence component.

The fact that nearly all hard γ rays are delayed relative to β's does not necessarily mean that all the hard γ rays are the lifetime-determining ones. It is quite possible that a low-energy transition at the top of the decay scheme is responsible for the lifetime entirely, or is in competition with one or more of the γ rays above 1 Mev in energy. It is interesting to note that an $M2$ transition of