

FIG. 1. Decay curve of the gamma-radiation from the neon sample bombarded with deuterons.

To determine whether the  $\text{Ne}^{23}$  gamma-ray has the energy to be expected on the basis of the beta-spectrum, an experiment was performed to determine the absorption curve for the gamma-radiation. The curve represents the ratio of the counts from the gamma-counter to the counts from a monitor counter attached to the pumping line. The result is shown in Fig. 2. Again, two

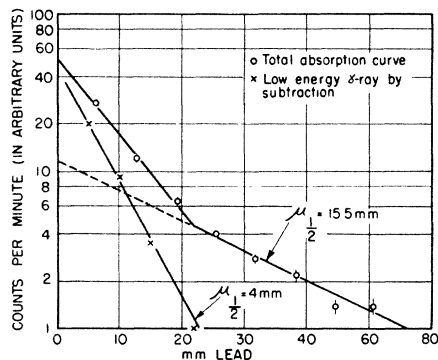


FIG. 2. Absorption curve in lead for the gamma-rays from  $\text{Ne}^{23}$  (plus  $\text{O}^{15}$  contamination).

gamma-rays are discernible. The low energy group has a half-thickness of 4 mm of lead, which corresponds to a gamma-ray energy of 500 kev, as would be expected from a positron-emitting contaminant. The high energy group has a half-thickness of 15.5 mm, corresponding to an energy of 2.8 Mev, but the absorption curve is so flat in this region that the energy might lie anywhere

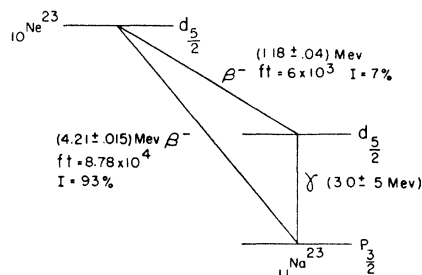


FIG. 3. Decay scheme for  $\text{Ne}^{23}$ .

from 2.5 to 3.5 Mev. This is the result to be expected if the low energy group of electrons from  $\text{Ne}^{23}$  represents a transition to an excited state of  $\text{Na}^{23}$ . The suggested level scheme is shown in Fig. 3.

The state of  $\text{Ne}^{23}$  is, according to the shell structure models,<sup>2</sup>  $3d_{5/2}$ . The ground state of  $\text{Na}^{23}$  should be, on these models,  $3d_{5/2}$ , but is anomalously found to exhibit a spin of  $\frac{3}{2}$ . This has been recently discussed by M. Mayer,<sup>3</sup> who suggests that it is due to a failure of pairing, so that three  $3d_{5/2}$  protons combine to give a  $\frac{3}{2}$  state. On this basis, one would expect that the high energy group, though allowed ( $\Delta J=1$ ) would have a rather small matrix element, and  $ft$  value  $\sim 10^5$  sec. because an extensive nucleonic rearrangement is involved. The excited state of  $\text{Na}^{23}$  may have the  $d_{5/2}$  configuration predicted for the ground state. In this case the low energy group would involve a  $d_{5/2} \rightarrow d_{5/2}$  transition, and its matrix element (and  $ft$  value) should be comparable to those of the mirror image nuclei, as we find to be the case. To make more certain the assignment of levels, coincidence experiments are planned.

We should like to thank Mr. P. Lindenfeld for his assistance with this experiment.

\* Assisted by the AEC.

<sup>1</sup> H. Brown and V. Perez-Mendez, Phys. Rev. **78**, 812 (1950).

<sup>2</sup> M. G. Mayer, Phys. Rev. **74**, 235 (1948); E. Feenberg, Phys. Rev. **77**, 771 (1949).

<sup>3</sup> M. G. Mayer, Phys. Rev. **78**, 16 (1950).

### Superconductivity of Isotopes of Mercury\*

B. SERIN, C. A. REYNOLDS, AND L. B. NESBITT  
Rutgers University, New Brunswick, New Jersey  
April 27, 1950

THE critical field measurements on enriched isotopes of mercury reported earlier<sup>1</sup> have been repeated and extended. The alternating field method used for determining the susceptibility has been extensively investigated by Shoenberg.<sup>2</sup> All the new measurements were made at a frequency of 100 c/sec. At this frequency, the ratio of sample radius to a.c. skin depth in the normal conductor is less than 0.6, so that there is a negligible signal from the imaginary part of the susceptibility. Under these conditions, as the external magnetic field is increased through the critical value, the a.c. signal goes through a maximum. The value of the magnetic field at this maximum was taken to be the critical field.

The transition temperatures for the samples obtained by extrapolating the critical field curves are given in Table I.

TABLE I. Transition temperatures for the Hg isotopes.

Av. mass number ( $M$ )	Transition temperature ( $T_0$ )°K
199.7	4.167
200.7 (natural mercury)	4.154
202.0	4.147
203.4	4.137

The critical field measurements were extended to lower temperatures and higher fields, and it was found that the curves for the isotopes were accurately parallel down to 2.30°K.

Table II shows the product  $M^3 T_0$  for the various isotopes. This product is quite constant, and is in fact more constant than any other simple combination of these variables. The constancy

TABLE II. The product  $M^3 T_0$  for the Hg isotopes.

Av. mass number ( $M$ )	$M^3 T_0$
199.7	58.88
200.7	58.84
202.0	58.93
203.4	58.99

of this product can be interpreted as showing that the ratio of the transition temperature to the Debye temperature of each of the lattices of the different isotopes is a constant, which indicates that the partition function of the lattice is a constant at the transition temperature.

A complete report on these measurements is being prepared.

\* This work was supported by the ONR, by the Research Corporation, by the Rutgers University Research Council, and by the Radio Corporation of America.

<sup>1</sup> Reynolds, Serin, Wright, and Nesbitt, Phys. Rev. **78**, 487 (1950).

<sup>2</sup> D. Shoenberg, Proc. Camb. Phil. Soc. **33**, 559 (1937).

### Transmutation-Produced Germanium Semiconductors

J. W. CLELAND, K. LARK-HOROVITZ, AND J. C. PIGG  
Oak Ridge National Laboratories, Oak Ridge, Tennessee  
April 6, 1950

GERMANIUM exposed in a nuclear reactor becomes a *P*-type semiconductor ("hole" or defect conduction).<sup>1</sup> It has been shown that this change is due to (a) lattice displacements produced by fast neutrons and (b) impurity centers produced by the transmutations due to slow neutrons. That this latter defect must exist became apparent when heat treatment at 450°C failed to restore the original conductivity in samples which had been exposed for a long period ( $nvt \sim 10^{18}$ ). The cross sections for activation given in the literature<sup>2</sup> lead to an *N*-type semiconductor and therefore K. Lark-Horovitz suggested a re-determination of the capture cross section on separated germanium isotopes. Such a determination was carried out by H. L. Pomerance,<sup>3</sup> and is shown in Table I.

The capture cross sections obtained by Pomerance predict an excess of *P*-type impurities (Ga) over *N*-type impurities (As).

$$N_e = nvt \times \sigma_e \times N_{Ge} \times P_i, \quad (1)$$

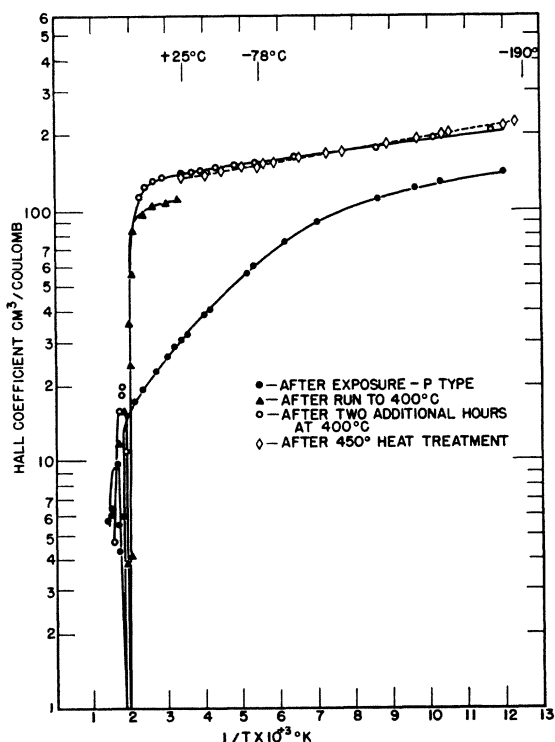


FIG. 1. Hall coefficient vs. temperature.

TABLE I. Absolute cross section of separated germanium isotopes.

(L. Seren, Argonne Laboratory)				
Isotope	Abundance	Capture cross section (in barns)		End product
		Isotopic	Atomic	
Ge <sup>70</sup>	21.2	0.073	0.0155	Ga
Ge <sup>76</sup>	21.2	0.45	0.095	Ga
Ge <sup>74</sup>	37.1	0.38	0.14	As
Ge <sup>76</sup>	6.5	0.085	0.0055	Se
(H. L. Pomerance, Oak Ridge Laboratory)				
Isotope	Abundance	Capture cross section (in barns)		End product
		Isotopic	Atomic	
Ge <sup>70</sup>	21.2	3.25	0.69	Ga
Ge <sup>72</sup>	27.3	0.94	0.26	Ge
Ge <sup>73</sup>	7.9	13.69	1.08	Ge
Ge <sup>74</sup>	37.6	0.60	0.22	As
Ge <sup>76</sup>	6.1	0.35	0.02	Se

where  $N_e$  is the number of events observed,  $nvt$  is the integrated neutron flux,  $\sigma_e$  is the cross section for the event,  $N_{Ge}$  is the number of atoms per cc in the material and  $P_i$  is the isotopic percentage of the atomic species. Therefore,

$$N_{Ga} - N_{As} = nvt \times 4.4 \times 10^{22} (3.25 \times 21.2 - 0.6 \times 37.6) 10^{-26} = 2.05 \times 10^{-2} nvt. \quad (2)$$

The impurity centers are formed at the lattice sites themselves. The semiconductor thus obtained, if one starts with "pure" single crystals of germanium, is therefore a substitutional alloy.

Germanium samples with known type and number of impurity centers (as determined by the Hall effect and the dissociation equation)<sup>4</sup> are exposed for various lengths of time in the reactor, in a region of determined flux. After exposure, Hall effect and resistivity are determined giving *P*-type centers due to (a) displacements (b) transmutations. The sample is then heat treated for various lengths of time at 450°C until further heat treatment no longer produces any changes. Provided the rate of cooling from 450°C does not freeze in any lattice defects, and that all displacements produced by knock-on collisions are completely annealed out at this low temperature, the resulting conductivity is now due to the originally introduced chemical impurities and the newly produced impurities from transmutations. The experimental results are shown in Figs. 1 and 2.

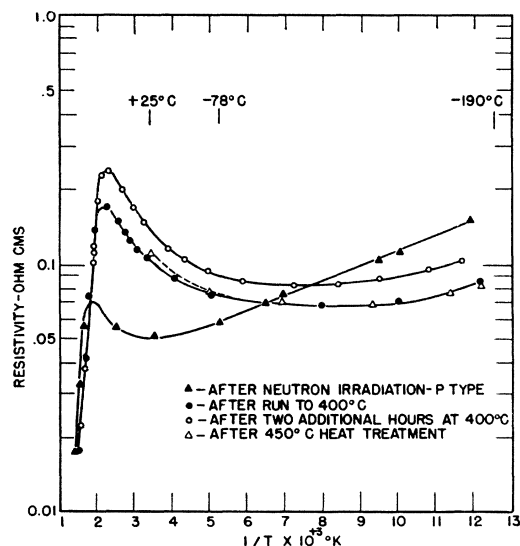


FIG. 2. Resistivity vs. temperature.