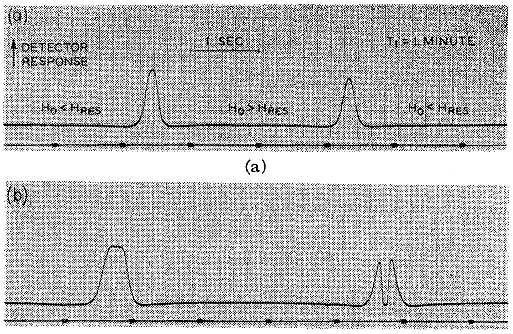

FIG. 1. Adiabatic fast passage through one phosphorus hyperfine line in silicon-28 at 1.2°K and ~9000 Mc/sec. In Fig. 1(a) the dc magnetic field was on for less than the relaxation time; the resulting small magnetization did not satisfy the oscillation condition. In Fig. 1(b) the oscillation condition was satisfied. Note that as a result of the emission the magnetization at the center of the line is destroyed.

or otherwise injecting carriers into it. The cavity was resonant at ~9 kMc/sec, and its loaded Q at 1.2°K was ~20 000.

In Fig. 1 we show the observed signals under adiabatic fast passage conditions. In Fig. 1(a) the oscillation condition *is not* satisfied. Going slowly from a magnetic field below resonance to one above, the magnetization of the sample is inverted and its energy increased. If we now slowly reduce the field to below resonance before the spins relax appreciably, we return the magnetization to its equilibrium value. In Fig. 1(b) the oscillation condition *is* satisfied. The trace shows that the magnetization near the center of the line is destroyed through reradiation which occurs during the first passage.

This immediate emission may be avoided conveniently either by decreasing Q_L or by increasing ΔH during the first passage. We increased ΔH by introducing a field inhomogeneity which was removed after the magnetization was turned over. Then we turned off the microwave signal generator and returned the magnetic field to resonance. Figure 2 shows the pulse of microwave power delivered by the spins to the cavity at this time. The maximum amplitude of the rf field in the cavity during the pulse was of order ΔH. This limit is imposed since the negative susceptibility of the sample decreases at greater field strengths. After the spontaneous oscillation was over, the residual magnetization could be detected by turning on the signal klystron and again observing a fast passage signal. It was found that the magnetization associated with the central portion of the line had inverted itself during the oscillation. The observed energy output obtained from the area under the curves of Figs. 2 and 3, and corrected for the cavity coupling (reflection coefficient =0.94), corresponded roughly to that given up by the spin system. By equilibrating the magnetization at a higher field, a larger output was obtained, as shown in Fig. 3.

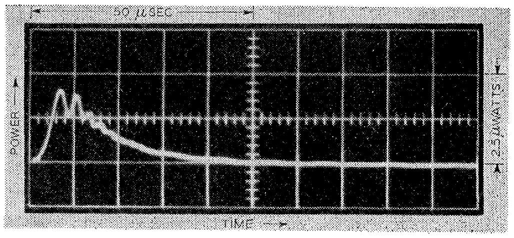

FIG. 2. Power output delivered by the spin system with the microwave oscillator turned off. The area under the curve agrees with calculated energy stored previously in the spin system.

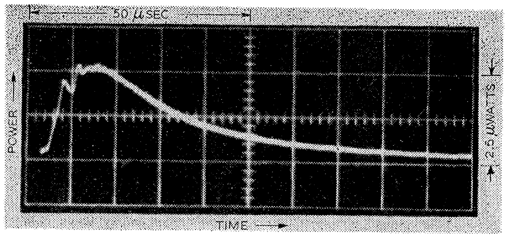

FIG. 3. Same as Fig. 2 with a large magnetization. The spin system was equilibrated at 8000 oersteds before letting it oscillate at 3000 oersteds.

The traces of Figs. 2 and 3 show a superimposed amplitude modulation which gradually diminishes, and has a frequency of approximately the line width. The exact origin of this effect is not clear at present. It presumably arises from an interference between different spin packets within the line.

We wish to thank Mr. M. Kowalchik for his assistance in preparing the sample.

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[1] Combrisson, Honig, and Townes, Compt. rend. **242**, 2451 (1956).

[2] Fletcher, Yager, Pearson, and Merritt, Phys. Rev. **95**, 844 (1954).

[3] We are indebted to the Isotope Division, Oak Ridge, Tennessee, for supplying us with 5 grams of an equal-mole mixture of Si and SiO_2 (99.98±0.02% Si^{28}). This was purified by us by making use of an aluminum reduction step, followed by a solution-precipitation step with molten tin. This procedure permitted 90% of the silicon to be recovered as fusible crystallites. This material was subsequently zone refined and doped with phosphorus to the desired concentration.

[4] G. Feher and R. C. Fletcher, Bull. Am. Phys. Soc., Ser. II **1**, 125 (1956).

Electrical Resistivity of Separated Lithium Isotopes*†

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IN the theory of electrical conduction in solids, the resistivity is a function of temperature and of atomic mass, and an involved functional of the atomic fields. The dependence of resistivity on temperature has been studied extensively by many investigators, but the dependence on atomic mass has been little studied in the absence of the complicating effects of changing the atomic field. To examine the mass dependence, we have chosen the isotopes lithium-6 and lithium-7, in view of their high relative mass difference, their availability in practical quantities, and their simple atomic and crystal structure.

Samples of separated isotopes were obtained from Oak Ridge National Laboratories. Wires of 1-mm diameter and 30-cm length were extruded through a steel die, and wrapped in a helical groove cut into a cylindrical Lucite support. Duplicate samples of the separated isotopes, together with natural lithium, were placed in a sample holder to be set in a cryostat. The resistance of the sample was measured with a precision Kelvin double bridge. The temperature was measured with a copper-constantan thermocouple from room temperature to 77°K. To determine the residual resistance at very low temperature, a reading was taken with the samples immersed in liquid helium at atmospheric pressure. The dimensions of the samples were not known well enough to permit an accurate determination of absolute resistivities, and hence only resistivities at temperature T relative to those at room temperature T_0 were studied. The ideal resistances, $R_{\mathrm{Li}^6}(T)$ and $R_{\mathrm{Li}^7}(T)$, were obtained by subtracting the resistances at 4.2°K from those at temperature T.

To test the adequacy of the Bloch-Grüneisen theory with respect to dependence of resistivity on atomic mass, we compare the experimental and the theoretical values of the ratio of the normalized ideal resistances for the two isotopes. By definition, we have

$$r_{\mathrm{exp}}=[R_{\mathrm{Li}^7}(T)/R_{\mathrm{Li}^7}(T_0)]/[R_{\mathrm{Li}^6}(T)/R_{\mathrm{Li}^6}(T_0)].$$

The theoretical value for the ratio is very nearly

$$r_{\mathrm{theo}}=G(\Theta_{\mathrm{Li}^7}/T)G(\Theta_{\mathrm{Li}^6}/T_0)/G(\Theta_{\mathrm{Li}^6}/T)G(\Theta_{\mathrm{Li}^7}/T_0),$$

where $G(z)\equiv 4z^4J_5(z)$, and J_5 is tabulated in standard references.[1]

For natural lithium (92.5% Li^7, 7.5% Li^6), Θ lies in the range[2] 330°K to 360°K; accordingly, Θ_{Li^7} may be taken in the range 325°K to 345°K. The reference temperature T_0 is 295°K. The ratio of Debye temperatures is nearly the reciprocal of the square root of the isotopic masses, $(6.017/7.018)^{-\frac{1}{2}}=1.080$.

Figure 1 shows the comparison of the excess over unity of r_{theo} and r_{exp}. The most reliable experimental values are those near 77°K, where equilibrium could be readily achieved. The observed effect is in the same direction but is less than half the amount predicted. It is concluded that the Bloch-Grüneisen scheme is adequate for gross predictions as to the effect of isotopic mass on electrical conductivity, but that it is unable to explain the details of the behavior. A similar conclusion was reached by McCaldin[3] in his work on the separated isotopes of iron. Before a more advanced theoretical analysis is undertaken, it appears desirable to measure the absolute resistivity and to extend measurements of relative resistance to temperatures below 77°K.

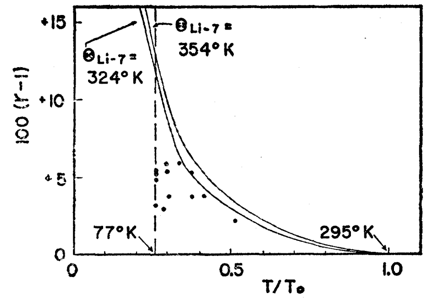

FIG. 1. Percent excess over unity of ratio of normalized ideal resistances for lithium isotopes, as a function of temperature. The curves show the theoretical results for two values of parameter as indicated; the circles show the experimental results.

We are grateful to Dr. P. S. Baker of Oak Ridge National Laboratory for assistance and advice in procuring and preparing the separated isotopes, and to R. G. Leffler of Michigan State University for help in making the measurements. An All-University grant from Michigan State University supplied loan fees for the initial samples.

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[1] See, e.g., A. H. Wilson, *Theory of Metals* (Cambridge University Press, London, 1953), second edition, Appendix A5.

[2] F. M. Kelly and D. K. C. MacDonald, Can. J. Phys. **31**, 147 (1953).

[3] J. O. McCaldin, California Institute of Technology Report, NP-5175, April, 1954 (unpublished).

Measurement of Beta-Ray Polarization of Au^{198} by Double Coulomb Scattering

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COMPLICATED instrumental effects have made it difficult to perform accurate and reliable measurements of beta-ray polarization.[1] It is therefore of value to have corroborating results by as many different independent methods as possible. The case of Au^{198} is of particular interest since early results indicating little or no polarization[2,3] are now believed to be in error. More recent experiments reported at the Rehovoth Conference[4–9] indicate full[10] polarization and are consistent with the conclusions reached at the conference that all beta rays are fully polarized.