ature dependence of C_{es} has been obtained from measurements by Goodman[11] on the thermal conductivity of superconducting tin below 1°K, which extended to values of T_c/T as large as 8. Here the electronic contribution to the thermal conductivity of the superconductor, which would be expected to be related to its electronic specific heat, also varied, over a wide range of temperature, in the exponential manner represented by Eq. (2).

On any single-electron model of a superconductor with a gap ϵ in the energy level spectrum, the expression for the specific heat would be expected to be dominated, at sufficiently low temperatures, by the term $\exp(-\epsilon/kT)$. The experimental evidence for vanadium, niobium, and tin discussed above supports the concept of such an energy gap; the magnitude of this energy gap, deduced from the experiments, is of the order of kT_c.

A full account of this work will appear in due course. The authors would like to acknowledge their gratitude to Dr. M. P. Garfunkel for his contribution to the experimental techniques used in this work.

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X-Ray Diffraction Patterns from Liquid Helium*

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INTENSITY as a function of scattering angle for copper $K\alpha$ x-rays has been determined for liquid helium (mass 4) at temperatures above and below its lambda point. Proportional counter registration of the scattered x-ray intensity was used together with a Ross differential x-ray filter and a differential pulse height analyzer for monochromatization and for spurious background reduction. Scattering angles from 1.5° to 90° were covered. The helium sample was contained in a one quarter inch diameter, thin-walled beryllium tube in good thermal contact with, but separate from, a temperature regulating helium bath. The sample temperature was determined from its vapor pressure.

The collimating and observation slit systems both permitted a maximum horizontal crossfire of $\frac{1}{3}$ degree. The vertical divergence for each slit system for scattering angles $>5°$ was about 7° and was decreased to about 2° for smaller angles. The scattering curves at 1.4°K and 4.2°K were repeated many times with a final estimated observational error in the curves of approximately ± 0.7 percent near the peak, ± 1 percent at 10° increasing to ± 4 percent at 1.5° and ± 1.5 percent at large angles. Only a small amount of data was taken at 2.2°K.

The resulting curves shown in Fig. 1 have been corrected for polarization, absorption in the helium, and for change of scattering volume with angle. The 1.4°K and 2.2°K data have been corrected to correspond to the number density at 4.2°K. These data are apparently in general agreement with the results of Keesom and Taconis[1] and of Reekie and co-workers[2] who state that there is little difference in diffraction patterns above and below the lambda point for scattering angle $>12°$. The diffraction peak at 1.4°K is shifted approximately 0.7° toward larger angles as might be expected for a density increase of 15 percent.

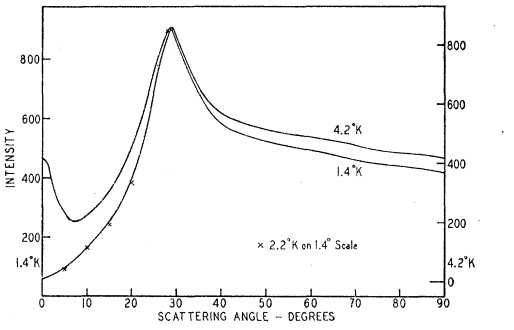

FIG. 1. Reduced scattering curves for liquid helium. The 1.4°K curve and the 2.2°K points follow the intensity scale, in arbitrary units, on the left while the scale on the right applies to the 4.2°K curve.

Two methods are available for reducing these corrected intensities to the liquid structure factors, $\mathfrak{L}(\lambda,\theta,T)$ at each temperature. The conventional approach[3] is that of determining the proportionality constant relating scattered intensities to the atomic scattering cross sections by assuming that at large scattering angles each atom scatters independently. Thus, the incoherently scattered portion can be subtracted using the computed incoherent cross section and the remaining coherently scattered intensity compared to the atomic structure factor. Because of the undulations observed near 90° this method is not entirely satisfactory here. Tweet[4] has suggested an alternative method using a comparison to the scattering from a gas whose scattering cross section must also be known. Argon gas was used in the present experiment and by requiring analytically that both methods give identical results for $\mathfrak{L}$ it was possible to determine the above proportionality constant

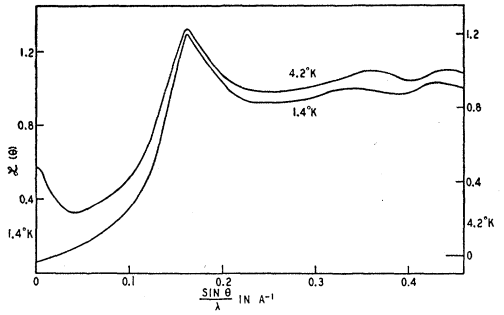

FIG. 2. Liquid structure factors for helium at 1.4° and 4.2°K. The ordinate scale on the left applies to the 1.4°K curve; that on the right to the 4.2°K curve.

unambiguously without consideration of the incoherent contribution.

Figure 2 shows the liquid structure factor curve at 4.2 and 1.4°K. In order that $\mathfrak{L}$ approach unity at 90° it was necessary to reduce the calculated incoherent scattering cross section of helium[5] by 10 percent. An overall increase of the calculated argon coherent scattering cross section by 10 percent would produce the same effect by reducing the proportionality constant for helium scattering, although of course the form of $\mathfrak{L}(\lambda,\theta,T)$ would be altered somewhat.

The liquid structure factor should approach zero scattering angle parabolically[6] with its limiting value given by $\mathfrak{L}(0°,T)=nkT\chi_T$, where n is the number density, k is the Boltzmann constant, T the absolute temperature, and χ_T the isothermal compressibility. Such a parabolic extrapolation for the experimental data in Fig. 2 yields a value for $\mathfrak{L}(0°,T)$ of 0.475 at 4.2°K and 0.065 at 1.4°K with a probable error of ± 7 percent as compared to 0.45 and 0.055 predicted by Goldstein in a private communication and approximately 0.6 at 4.2°K according to Tweet.[4]

Details of the experiment will be published shortly.

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Electrical Resistivity Minimum and Structural Defects in Copper

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BLEWITT, Coltman, and Redman[1] have reported that a resistance minimum was observed in pure copper upon introducing grain boundaries by straining a single crystal and subsequently annealing it. The original single crystal as well as the strained, unrecrystallized sample, however, did not show a minimum. The authors therefore proposed that the minimum in electrical resistivity may arise as a result of scattering or trapping at grain boundaries.

If this proposal were true, one might expect alterations in the grain structure of copper to produce changes in any resistivity minimum observed. Experiments done at this Laboratory indicate that no such effect occurs. These experiments consist of measuring the small minimum occurring in cold-drawn copper wires and in the same samples after they are subjected to annealing treatments. The copper is American Smelting and Refining Company high-purity copper,[2] samples $0-A$ having been prepared by swaging and cold drawing the original stock into wires, sample $0-B$ by chopping the stock into pieces and remelting in evacuated quartz tubes prior to swaging and drawing. The results are illustrated in Fig. 1, where $\rho_{\text{anom}}\equiv\rho_T-\rho_{4.2°\text{K}}$ *vs* temperature is plotted for the liquid helium temperature region. Earlier measurements on $0-A$ show no signs of a resistance minimum, whereas recent, more precise measurements show a slight minimum of the order of or less than that observed by MacDonald[3] in his pure copper (the quantity δ indicated in the figure represents approximately MacDonald's value of $\rho_{4.2°\text{K}}-\rho_{\min}$). The pertinent observation on this sample is that after being

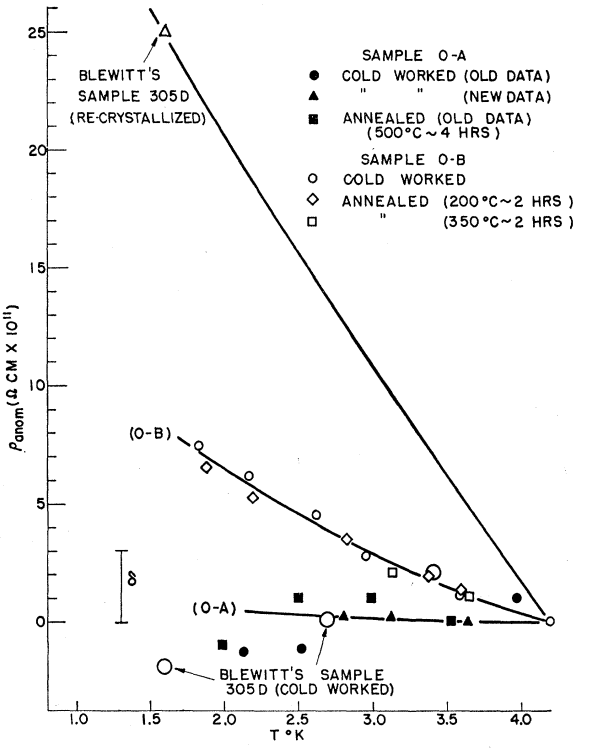

FIG. 1. $\rho_{\text{anom}}\equiv\rho_T-\rho_{4.2°\text{K}}$ *vs* temperature for copper samples.