Table II. Width of energy distribution of neutrons scattered through 80°.

Experimental liquid helium		Calculated for free particles; m=2.6 helium masses	
Liquid Temperature °K	Full width at half maximum °K	Particle temperature °K	Full width at half maximum °K
1.27	< 0.5	0.5	6.4
1.57	~1	...	...
2.08	8.5	2	12
4.21	22.5	4	17.3

The measured and calculated widths for temperatures at and above the λ point are similar, while for temperatures below the λ point the measured widths are very small compared to the calculated widths. The major portion of the change occurs between the λ point and 1.6°K, the region of the maximum in the specific heat anomaly. This suggests that the λ transition is associated with a marked change in the atomic motions.

Preliminary measurements of the distribution of neutrons scattered through 80° by liquid helium at 1.4°K have been made at pressures of 3.7 and 21.4 atmospheres using the rotating-crystal spectrometer. These results indicate that the spectrum at 21.4 atmospheres is broader and the maximum is at a shorter wavelength than at 3.7 atmospheres. The difference between the two curves indicates that the energy change of the scattered neutrons is lower by about 1°K at the higher pressure. This change is consistent within experimental error with the expected decrease in Δ/k of about 0.8°K predicted by the theory of Landau [12] for a change in liquid pressure from 0 to 25 atmospheres.

Further measurements are being made and the analysis of these measurements is continuing.

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LOW-LEVEL ABSORPTION IN GERMANIUM†

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Values of the absorption coefficient of Ge near the band edge have been extended to much lower levels by measurements of photoconductivity of suitable specimens. These specimens were thin bars of cross section 5×0.5 mm² and length ~4 cm. The radiation from a monochromator was focussed onto one end face. Reflections from the other end face were eliminated by coating the surface with a layer of PbS which has the same refractive index as Ge and an absorption coefficient ~10^4 cm^{-1} in the 2μ region.

Electrodes were soldered to the sides of the bars a few mm from either end. The Ge between the front surface and the first electrode acts as a filter which reduces the sensitivity of the device at short wavelengths, thus minimizing the effects of any scattered radiation when measuring the low signals obtained at the longest wavelengths.

The sides of the bar were etched with superoxol to give low surface recombination. Under these conditions the photoconductive signal is proportional to the total absorption in the sample, i.e.,

$$S \propto \int_{t_2}^{t_1} K \exp(-Kx)\, dx \quad \text{or} \quad S = A\exp(-Kt_1) - A\exp(-Kt_2),$$

where A is a constant and t_1, t_2, are the distances of the electrodes from the illuminated end.

For the first specimen, where $t_1 = 2$ mm and $t_2 = 34$ mm, it is readily shown by differentiation of the above equation that maximum signal occurs at $K = 0.90\ \mathrm{cm}^{-1}$ when $S_{max} = 0.81A$. Hence $0.81\ S/S_{max} = \exp(-Kt_1) - \exp(-Kt_2)$. From this equation absolute values of K are readily obtained for any value of S. For later specimens, t_1 was increased to ~5 mm.

All the Ge used was 50 ohm-cm, p type. A double monochromator with silica prisms was used, particular care being taken to maintain high spectral purity of the radiation. The spectral bandwidth was 0.005 ev.

The results for 15°C are shown by the points in Fig. 1, from which it may be seen that absorption coefficients as low as $10^{-5}\ \mathrm{cm}^{-1}$ were measurable. The dashed line shows the lowest values given by Macfarlane *et al.*[1] - obtained from transmission data at 18°C. The agreement is seen to be good.

It is clear that absorption producing free carriers is still taking place at energies <0.57 ev,

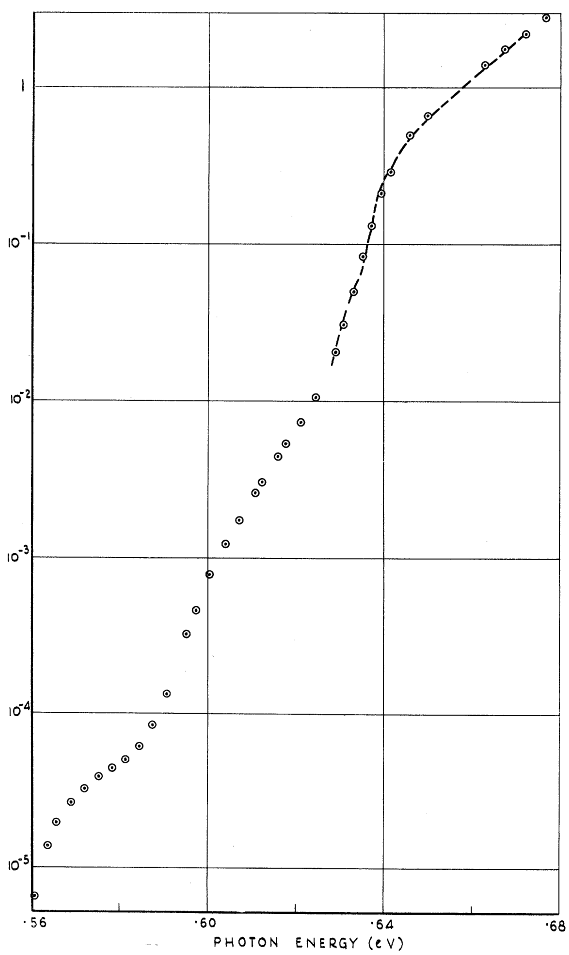

FIG. 1. The low-level absorption edge of germanium at 14°C.

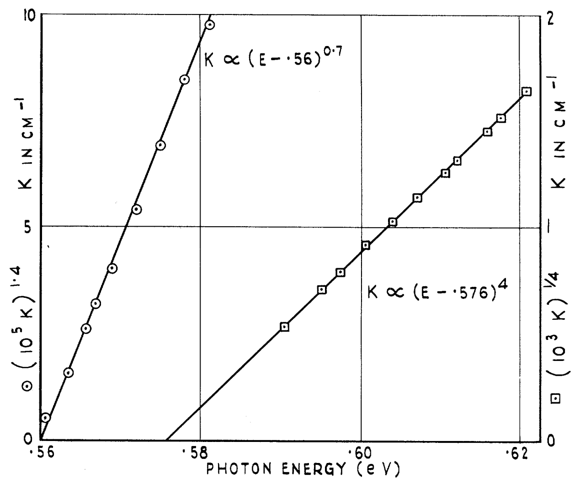

FIG. 2. Analysis of absorption in germanium.

which contrasts with the energy gap of 0.669 ev.[1] Two well defined parts of the absorption spectrum are analyzed in Fig. 2; they show that in the 0.59 - 0.62 ev region the absorption is well represented by

$$K \propto (E - 0.576)^4,$$

while at the lowest levels one has

$$K \propto (E - 0.560)^{0.7}.$$

These energy thresholds are thus 0.093 ev and 0.109 ev, respectively, less than the energy gap.

The mechanism of these low-energy transitions is not yet established, but it is possible that the highly energy-dependent term is associated with transitions from occupied acceptors to the conduction band or to empty donor levels. Also multiple phonon effects may be important.[2]

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[1]Macfarlane, McLean, Quarrington, and Roberts, Phys. Rev. 108, 1377 (1957).

[2]A likely second-order process to explain the lowest absorption band involves simultaneous transitions from valence maximum to the conduction maximum and from $k \sim 0$ in the conduction band to the conduction mininum — in the opposite direction — requiring an energy of 0.67-(0.80-0.67), or 0.54 ev.