We have calculated the vapor pressure difference $\Delta P(=P-p_4^0)$ for a four percent solution of He^3 in He^4 on the basis of our model by making use of the linear and quadratic expressions for G_4. The results thus obtained are compared with various theories[2-4] and the experimental results.[1,9] The vapor imperfection corrections have been applied using the second virial coefficients computed by Kilpatrick *et al.*[10] It is evident from Fig. 1 that the present model, especially with the linear expression for G_4, describes the observed behavior better than the other theories.

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Effect of Copper on Ultrasonic Attenuation in Germanium*

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IT has been shown[1] that ultrasonic attenuation in germanium can be attributed to the damped forced oscillation of dislocation segments. Following this idea, an attempt was made to decrease the attenuation by diffusing impurities into the specimen to pin down the dislocations.

Application of dislocation theory[2] leads to the result that the attenuation for the lower part of the frequency range measured should be given by

$$\alpha=\frac{2\Omega\Delta_0\Lambda L^4Bf^2}{\pi C}(8.7\times10^{-6}), \qquad (1)$$

where α is the attenuation in decibels per microsecond, Ω is an orientation factor, Δ_0 is a constant for a given material, Λ is the dislocation density, L is the effective loop length, B is a damping constant, f is the frequency, and C is the line tension of the dislocation. Using the values [see references (1) and (2)] $\Omega\Delta_0=1/20$, $\Lambda=2\times10^6$ cm^{-2}, $L=10^{-4}$ cm, $B=10^{-4}$ g sec^{-1}cm^{-1}, and $C=1.6\times10^{-4}$ dynes, one obtains $\alpha=0.3$ db/μsec for $f=10^8$ cycles/sec which is a typical measured value for this frequency.

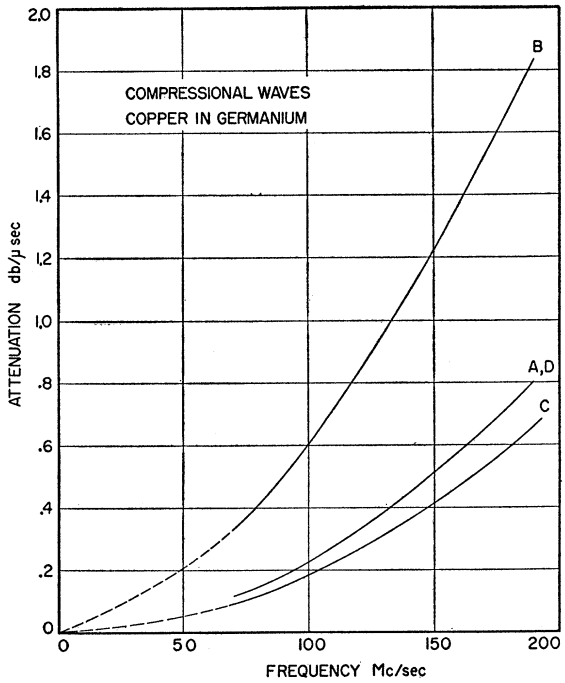

FIG. 1. Attenuation as a function of copper present. Compressional wave attenuation. (A) crystal as originally measured; (B) after heating at 800°C in vacuum; (C) after diffusion of copper into specimen; (D) after reheating in vacuum.

For very pure specimens, the loop length L should be given by the length of the Frank-Read sources, or the network lengths, and as impurities are added, the loop length should be descreased by the pinning action of the impurities. Since the attenuation is determined by the fourth power of the loop length, the attenuation should be very sensitive to impurities.

The attenuation of compressional and transverse waves was measured in a germanium single crystal for waves propagating in the [100] direction. The specimen was first heated at 800°C for fourteen hours in vacuum to drive out impurities.[3,4] The crystal was then (after making attenuation measurements) plated with copper and heated again to diffuse the copper through the germanium. The attenuation results are shown in Figs. 1 and 2; they are qualitatively as expected. After vacuum heat treatment the attenuation of compressional and transverse waves has increased by factors of approximately $2\frac{1}{2}$ and 4 respectively, and after copper is added the attenuation decreased by factors of $3\frac{1}{2}$ and 9 respectively.

The added copper can affect the dislocation loop lengths in two ways. One way is that of pinning the dislocations by individual copper atoms in solution in the germanium, and the other is by the formation of precipitates along the dislocations. The concentration of copper atoms on the dislocations should be larger than in solid solution because the copper atoms can by their presence reduce the strain at dislocations. It can

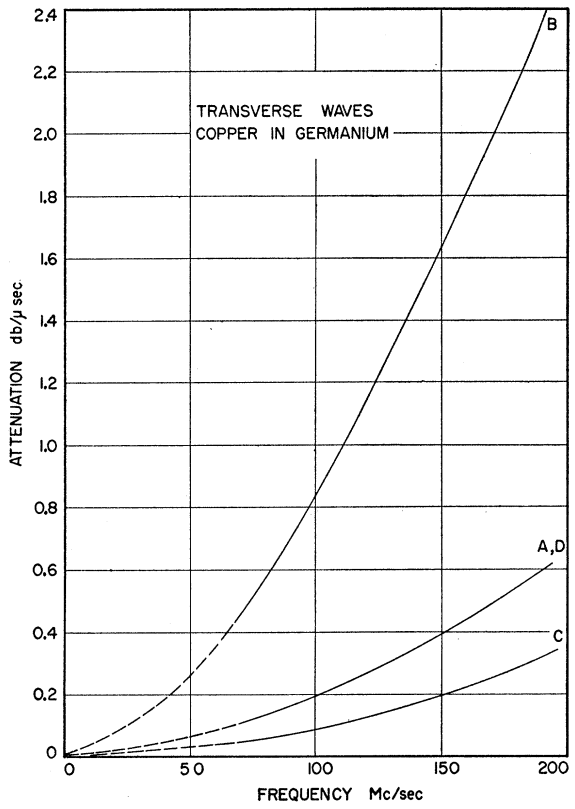

FIG. 2. Attenuation as a function of copper present. Transverse wave attenuation. (A) crystal as originally measured; (B) after heating at 800°C in vacuum; (C) after diffusion of copper into specimen; (D) after reheating in vacuum.

be shown, however, that because the solubility of copper in germanium is quite low (maximum solubility[5] is about 4×10^{16} atoms/cc), there is, excluding the possibility of precipitation effects, not sufficient copper on the dislocations to account for the magnitude of the attenuation change observed. It seems that the precipitation of copper on dislocations is responsible for the large observed changes; additional evidence for this can be found in resistivity measurements.[6]

Experiments are under way to determine quantitatively the effect of precipitated copper in connection with the observed effects. Attenuation changes have already been shown to be a sensitive method of indicating precipitation effects in internal oxidation in dilute copper alloys. It is expected that in this case with copper in germanium the attenuation changes will also prove to be a sensitive method of studying precipitation effects.

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Empirical Determination of Nuclear Moments of Inertia and Intrinsic Quadrupole Moments

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AN empirical parameter, k, has been found which enables one to calculate the fractional nuclear mass or charge which takes part in collective phenomena for a given even-even nucleus. This parameter is defined as the ratio of the number of particles outside of filled major shells (both protons and neutrons) or the number of holes, whichever is smaller, to the total number of particles in the nucleus.

If one assumes that the fractional nuclear mass, kM, where M is the mass of the nucleus, rotates about an axis at right angles to the axis of symmetry, as an axially-symmetric rigid rotator with uniform mass distribution, the moment of inertia is given by $\Lambda_x=\frac{1}{5}kMR_0^2(\gamma^2+\alpha^2)$, where γ is the distance along the axis of symmetry in units of R_0, α is the distance along the axis at right angles to the axis of symmetry, and R_0 is the undeformed nuclear radius, here taken to be $1.44\ A^{\frac{1}{3}}\times10^{-13}$ cm. The energy of such a rigid rotator with angular momentum λ is given by $E_\lambda=(\hbar^2/2\Lambda_x)\times\lambda(\lambda+1)$. The intrinsic quadrupole moment, Q_0, is defined by $\int\rho r^2(3\cos^2\theta-1)d\tau$. For the case of an axially-symmetric rigid rotator with uniform charge distribution, $Q_0=\frac{2}{5}ZR_0^2(\gamma^2-\alpha^2)$. Under the assumption that the deformation is volume-preserving, $\alpha^2\gamma=1$.

Thus, using the above relationships together with the known number of nucleons in a given nucleus and the measured energy of its first-excited 2^+ state (when it is known to be a member of a pure rotational sequence), one can obtain the intrinsic quadrupole

TABLE I. Intrinsic quadrupole moments, $Q_0(E_{2^+})$, and shape factors, γ, obtained from the energies of first-excited states; and intrinsic quadrupole moments, $Q_0(\mathrm{B-M})/k$, obtained from transition data. The moments are given in units of 10^{-24} cm^2.

Nucleus	k	E_{2^+} (kev)	γ	$Q_0(E_{2^+})$	$Q_0(\mathrm{B-M})$	$\frac{Q_0(\mathrm{B-M})}{k}$	$\frac{Q_0(\mathrm{B-M})/k}{Q_0(E_{2^+})}$
$_{64}Gd^{154}$	0.1428	123	1.83	42.7	6.6	46	1.08
Gd^{156}	0.1538	89	2.10	60.5	8.4	55	0.91
Gd^{158}	0.1646	79	2.14	63.8	9.3	56	0.88
Gd^{160}	0.1750	76	2.08	60.2	9.8	56	0.93
$_{66}Dy^{160}$	0.1750	86.2	1.93	51.7	7.1	41	0.79
Dy^{162}	0.1852	82	1.90	50.2	7.9	43	0.86
Dy^{164}	0.1951	73	1.95	54.0	9.2	47	0.87
$_{68}Er^{164}$	0.1707	91	1.85	48.7	7.3	43	0.88
Er^{166}	0.1807	80	1.91	53.2			
$_{70}Yb^{170}$	0.1765	84.1	1.83	49.9	7.1	40	0.80
$_{72}Hf^{176}$	0.1818	87	1.69	42.5	7.1	39	0.92
Hf^{178}	0.1685	90	1.72	44.9	7.7	46	1.02
Hf^{180}	0.1556	93	1.75	47.4	7.2	46	0.97
$_{74}W^{180}$	0.1556	102	1.65	41.4			
W^{182}	0.1428	100	1.75	49.1	7.0	49	1.00
W^{184}	0.1304	112	1.70	45.7	6.7	51	1.12
W^{186}	0.1183	124	1.67	43.8	5.9	50	1.14