

spectrum, N/V is the number of atoms per unit volume, v_t and v_l are the transverse and longitudinal acoustic velocities respectively, h is Planck's constant, and k is Boltzmann's constant. In a liquid one cannot measure v_t with the ultrasonic frequencies available in the laboratory but if one assumes that the liquid behaves as an isotropic elastic medium and chooses a value for Poisson's ratio, σ , let us say equal to 1/3, then the value of v_t can be calculated. Since the low frequency transverse modes make only a small contribution to the vibration spectrum of the liquid, its Θ_D can be found to a good approximation from Eq. [4]. The calculated values of Θ_D are not overly sensitive to the choice made for Poisson's ratio, σ . The table below indicates this sensitivity for the case of liquid mercury.

σ	Θ_D
0.2	133°K
0.33	99.7
0.4	76.7

An interesting comparison can be made of the two pure liquid metals, mercury and gallium. The extremely low melting temperature of mercury is indicative of the weak bonding existing in the solid state. The normal volume expansion on melting further weakens the interatomic bonding as evidenced by the low boiling point of the liquid. The element, gallium, on the other hand, has a low melting point but a rather high boiling point indicative of strong bonding in the metallic liquid. The respective temperature data are shown below:

	T_m (°K)	T_b (°K)	T_b/T_m	Θ_D (°K)
Hg	235	630	2.68	100
Ga	303	2256	7.45	206

The low Θ_D of mercury is typical of a metal with weak bonding forces.

The electrical resistivity of a metal, ρ , is dependent in part upon the atomic vibration amplitude and can be related to the characteristic temperature as follows:

$$\rho \propto \frac{T}{m\Theta_D^2} \quad (T > \Theta_D) \quad [6]$$

where T is the absolute temperature and m the atomic mass. A change in Θ_D due to alloying will then change the resistivity by an amount

$$-\frac{1}{2} \left(\frac{\Delta\rho}{\rho} \right) \propto \left(\frac{\Delta\Theta_D}{\Theta_D} \right) \quad [7]$$

The total change in resistivity due to alloying will include the change in the thermal part of the resistivity

calculated above plus the changes due to scattering by the solute atoms (always an increase) and any alteration of the effective number of conduction electrons (which may be an increase or a decrease). Recorded in Table IV is the change in characteristic temperature, $\Delta\Theta_D/\Theta_D$, due to alloying calculated from the observed velocity of sound and the corresponding $\Delta\Theta_D/\Theta_D$ from Eq. [7] obtained when $\Delta\rho$ is set equal to the observed resistivity change. The resistivity data of Schultz and Spiegler¹⁹ are used in this table. It is remarkable, first of all, that the sign of the $\Delta\Theta_D$ obtained from the sonic velocity and the resistivity is the same and that the magnitudes are comparable. Evidently a substantial part of the resistivity change which occurs upon alloying mercury is due to an alteration of the vibration spectrum of the liquid. The differences in the $\Delta\Theta_D$'s calculated by the two methods is due to the above-mentioned factors, solute scattering and change in the effective number of conduction electrons, N_{eff} . In the case of thallium, tin and lead it is evident that there must be an increase in N_{eff} since the observed resistivity is lower than it would be on the basis of the change in Θ_D alone. In the case of bismuth and cadmium one concludes that either solute scattering prevents the resistivity decrease from being as great as it should be otherwise or that N_{eff} is not so much increased by these solutes. The case of potassium is somewhat special as this solute atom is considerably larger than the mercury atom and appreciably different in electronegativity. There is a strong tendency to form compounds in the alkali amalgams as evidenced by the strongly exothermic heat of solution,²⁰ and some of the resistivity increase probably arises from scattering by alkali-mercury "complexes" or "molecules."

Among the solutes listed in Table IV (with the exception of the special case of potassium) there are variations of size and valence, some of the solutes enter solution endothermally and some exothermally, yet all increase the Debye temperature and decrease the resistivity. This is again suggestive of an alteration of the mercury structure which is not particularly sensitive to the nature of the solute producing it. Further evidence of this is found in the magnetic susceptibility measurements of Bates and Somekh:¹⁸ these solutes all make the mercury more paramagnetic. This and the resistivity decrease greater than that expected on the basis of $\Delta\Theta_D$ for thallium, tin, and lead suggest that the structural change in mercury is accompanied by an increase in the effective number of conduction electrons.

d) Structural Change in Amalgams. Mercury is one of the group II B metals characterized by a remarkable and unique set of properties: zinc and cadmium display a very high, nonideal c/a ratio and limited solid solubility for most other elements. As liquids they display a resistivity minimum with increasing temperature. The rhombohedral struc-