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isothermal measurements of the change of volume of sodium with pressure at 273°K and Swenson's[13] measurements at 4.2°K.[14] The agreement of the presently found values of the shear constants with the extrapolation of the results obtained by Quimby and Siegel is considered within the error of the extrapolation. The value of B_s found by us is less than 1% lower than the value we obtain from Bridgman's data. We do not know the explanation of the very large difference between the Quimby and Siegel value of B_s and that found by other investigators. The theoretical values of C and C' due to Fuchs' for 0°K are also presented.

An analysis of the present measurements of the pressure variation of the adiabatic elastic constants of sodium at room temperature is given in Table II, together with results obtained from data by Bridgman[12] and Swenson.[13,14] Note that the result for dC_{44}/dP is based on three crystals of two different orientations, [110] and [100] and the result for dC'/dP is based on

TABLE II. Analysis of the pressure derivative data for sodium. [The quantity $(1/T)(dT/dP)$ is the fractional change of transit time of an acoustic pulse echo per unit pressure change. The units are 10^{-11} cm² dyne⁻¹. These are the results closest to the original measurements and are presented for comparison].

	$(1/T)(dT/dP)$	dC/dP
C	1.74[100] 1.65[110] 1.67[110]	1.63
C'	1.65[110] 1.69[110] 1.70[110]	0.226
$C_{11'}$[a] Present B_s Bridgman[b] Swenson[c]	0.216[110]	5.30 3.60 3.30 4.13

[a] $C_{11'} = \rho v_{\text{long}}^2$.
[b] dB_T/dP derived from dilatometric data.[12]
[c] From dilatometric data taken at 4.2°K.[13]

three [110] crystals of different lengths. The measurements of dB_s/dP are derived from four runs made on a single [110] crystal. More extensive measurements of dB/dP were not made at this time because it is intended to repeat all measurements of the pressure variation of the elastic constants of sodium at several temperatures below 300°K in order to estimate the error in assuming the results to apply at 0°K. It should

[14] The dilatometric data by Bridgman[12] and Swenson[13] are $\Delta V/V_0$ vs pressure. We found the compressibility and its pressure derivative at zero pressure by plotting $(1/P)(\Delta V/V_0)$ from their data and drawing a smooth curve through to points thus obtained. The intercept of this curve on the $P=0$ ordinate is the initial compressibility, $\chi_T = (1/V)(dV/dP)_T$ and the initial pressure derivative of the compressibility may be found using the relation: $dB_T/dP = 2a_2/a_1^2 - 1$ where a_2 is the initial slope and a_1 the intercept of the curve. Then using the relation

$$B_s = B_T(1 + TV\beta^2 B_T/C_P)$$

we have computed a value of B_s from the Bridgman data. At temperatures as low as 4.2°K, the difference between B_s and B_T is negligible.

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be mentioned here that the nature of the ultrasonic pulse echo method is such that the variation of the shear constants is measured directly; i.e., each is independent of measurements made on the other, while in general, determination of the variation of B_s involves use of measurements of the variation of both C_{44} and C' as well as the longitudinal data.[3]

Room temperature for all of these measurements is 299°K±1°K.

INTERPRETATION OF RESULTS

The elastic constants of a crystal can be expressed as the second derivatives of the crystal binding energy with respect to the appropriate strain. The conventional model[15] on which elastic constant calculations are based considers that the only important contributions to the elastic constants arise from (1) a long range Coulomb interaction between the charged particles making up the crystal, (2) the Fermi energy, and (3) a short range repulsive interaction between closed shell ion cores.

The pressure variation of the elastic constants of copper, silver and gold,[3] and of aluminum and magnesium[10] have been interpreted in these terms. In the series of monovalent noble metals copper, silver and gold, the ion core term (3) predominates, while in the polyvalent metals aluminum and magnesium, the Fermi term (2) represents an important contribution to both the shear elastic constants and the bulk moduli, as well as to their pressure derivatives.

In the case of the alkali metals on the other hand, the ion cores are so widely spaced relative to their diameters that the contribution their interaction makes to the elastic constants may be neglected. Also, the alkali metals are monovalent; one expects the Fermi surface to be nearly spherical, to lie entirely inside the first Brillouin zone, and to remain unchanged by elastic distortions which do not change the volume of the crystal. Thus one can neglect the contribution (2) to the elastic shear constants of this series of metals. The Fermi energy will, of course, contribute to the bulk moduli of these materials, and is in fact the major contributor to it. This leaves only the contribution (1) due to the long range Coulombic interactions to account for the values of the elastic shear constants of the alkali metals.

Fuchs[2] has calculated the Coulomb contribution to the elastic shear stiffnesses of the alkali metals of 0°K on the basis of a model consisting of a lattice of positive point charges at atom sites, imbedded in a uniform sea of electronic charge. Since a number of investigators[16] have shown that the electronic wave function is constant over most of the volume of the alkali metal crystals,

[15] N. F. Mott, *Progress in Metal Physics*, edited by Bruce Chalmers (Interscience Publishers, Inc., New York, 1952), Vol. 3, pp. 90–94.

[16] See for example F. Seitz, *Modern Theory of Solids* (McGraw-Hill Book Company, Inc., New York, 1940), Chap. X.