

each point. Transition temperature rather than change in transition temperature is plotted due to the lack of reproducibility of the atmospheric pressure T_c after releasing the applied pressure. It is concluded that the T_c for lanthanum is sensitive to internal strains, and this is reflected in the variation of T_c on removal of the applied pressure. Despite this variation in the values of T_c at atmospheric pressure there is a roughly linear dependence of the transition temperature with applied pressure. ($\partial T_c/\partial P \sim 14 \times 10^{-5}$ °K/bar).

Measurements 2 and 21 are of special interest as two distinct transitions, approximately 1°K apart, were observed at pressures of 5150 and 5980 bar, respectively. On removal of the pressure the two transitions remained, but were displaced to lower temperatures (points 3 and 22). This behavior was observed in both samples examined, points 2 and 3 being for the Lunex sample and 21 and 22 for the U.S.B.M. Annealing at 250°C for several hours removed the double transition at atmospheric pressure in both cases (points 4 and 23). This behavior was not repeated in a subsequent measurement (point 10) on the Lunex sample in this pressure range. It should be noted that no anomalies in the compressibility¹⁷ and the electrical resistance¹⁸ have been reported in this pressure range.

III. DISCUSSION

Thus the observed increase of T_c with applied pressure precludes the models of Kondo and Kuper *et al.* for the superconducting mechanism in lanthanum, if the premise that the application of pressure raises the $4f$ level relative to the Fermi surface is accepted. This observed increase is, however, in qualitative agreement with the observed volume change and a direct application of the Clausius-Clapeyron relation. Using data obtained on the critical field behavior of lanthanum, his measured volume change and the compressibility, Rohrer⁹ estimated a value of $d \ln T_c / d \ln V \sim -0.5$. From the observed $d T_c / d P$ in the present work and the room temperature compressibility of lanthanum we estimate a value of $d \ln T_c / d \ln V \sim -6$, which is an order of magnitude greater than that given by Rohrer. This

¹⁷ P. W. Bridgman, *Am. Acad. Arts. Sci.* **76**, 55 (1948).

¹⁸ P. W. Bridgman, *Am. Acad. Arts. Sci.* **79**, 149 (1951).

discrepancy is perhaps not surprising in view of the irreversible magnetic behavior of lanthanum.¹⁴

If we adopt a BCS approach to the superconducting behavior of lanthanum then the maximum increase in T_c under pressure may be accounted for by an increase of 8% in the density of states, if we assume the electron-phonon interaction is constant. Such an increase is quite feasible if the Fermi energy of lanthanum occurs near a peak in the density-of-states curve and this is not unreasonable since lanthanum is an element with a high density of states.¹³ However, a high density of states alone is not sufficient to account for the superconducting behavior of lanthanum since scandium, yttrium and lutetium have roughly the same value for their densities of states¹⁹ and are not superconducting above 0.1°K. We think, therefore, that the amount of f admixture in the wave functions at the Fermi energy must be an important feature in the superconductivity of lanthanum.

Finally it may be argued that part of the increase in T_c is associated with the transition of the hcp phase to the fcc under pressure. However, we think such an explanation is unlikely since the transformation pressure at room temperature for hcp to fcc is believed to be ~ 23 kbars.^{17,20-23} Some unsuccessful attempts have been made to obtain the fcc phase of lanthanum by quenching from 600°C. We were, however, unable to obtain a sample with a sharp superconducting transition around 6.0°K. This may be because the sample size ($\frac{3}{8}$ -in.-diam. $\frac{3}{8}$ -in.-long cylinders) was too great and hindered the fast quench necessary to retain the fcc phase.

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¹⁹ H. Montgomery and G. P. Pells, *Proc. Phys. Soc. (London)* **78**, 622 (1961).

²⁰ F. Barson, S. Legvold, and F. H. Spedding, *Phys. Rev.* **105**, 418 (1957).

²¹ D. B. McWhan, P. W. Montgomery, H. D. Stromberg, and G. Jura, *J. Phys. Chem.* **67**, 2308 (1963).

²² G. J. Piermarini and C. E. Weir, *Science* **144**, 69 (1964).

²³ D. B. McWhan and W. L. Bond, *Rev. Sci. Instr.* **35**, 626 (1964).