The analysis of the data obtained at helium temperatures is considerably simplified by the assumption of strong statistical degeneracy. An expression for the electron concentration is obtained as follows. For a spherically symmetrical conduction band the electron concentration is given by

$$n = k_F^3/3\pi^2 \ , \tag{1}$$

where $k_F$ is the electron wave vector at the Fermi surface.

The $E(\vec{k})$ relationship for the conduction band from $\vec{k}\cdot\vec{p}$ theory for the case of $kP_K$ and $E_g$ very much less than the spin-orbit splitting energy is[4]

$$E(k) = \frac{\hbar^2 k^2}{2m_0} + \frac{E_g + (E_g^2 + \frac{8}{3}k^2P_K^2)^{1/2}}{2} \ , \tag{2}$$

where $P_K$ is the Kane matrix element, and the energies are measured from the valence-band edge. The first term is negligible for the narrow-gap alloys. By replacing $E(k)$ and $k$ by their values at the Fermi level, $E_F$ and $k_F$, and rearranging, we obtain (for $E_F > E_g$)

$$k_F^2 = \frac{3}{2P_K^2} E_F(E_F - E_g) \ . \tag{3}$$

Combining Eqs. (1) and (3) yields

$$n^{2/3} = \left(\frac{1}{3\pi^2}\right)^{2/3} \frac{3}{2P_K^2} E_F(E_F - E_g) \ . \tag{4}$$

On substituting $E_g = E_0 + \alpha P$ this becomes

$$n^{2/3} = \left(\frac{1}{3\pi^2}\right)^{2/3} \frac{3}{2P_K^2} E_F(E_F - E_0 - \alpha P) \ . \tag{5}$$

The expression is valid in both the normal- and inverted-band-structure regions, provided that the correct sign is used for $E_0$ ($E_0$ is negative for the inverted band structure).

The electron concentrations obtained experimentally at 4.2 °K for the three samples are shown in Fig. 8, plotted as $n^{2/3}$ vs $P$. A straight line is obtained in each case, indicating that the position of the Fermi energy relative to the valence-band edge is independent of pressure. The slope of the line yields $\alpha E_F/P_K^2$. $E_F$ is found by taking $\alpha = 7\times10^{-3}$ eV/kbar (the value obtained at 77 °K) and $P_K = 8.4\times10^{-8}$ eV cm.[5] $E_0$ is then obtained from $E_F$ and the intercept on the pressure axis. The values of $E_F$ and $E_0$ found in this way are given in Table II. The small difference in $E_0$ for samples 7B1 and 7B, which were taken from the same slice of the parent crystal, could be due to an undetected difference in alloy composition. The required difference in $x$ is 0.004, which is within the experimental error of the microprobe analysis. Values for $E_0$ calculated for the measured values of $x$ from empirical expressions[8,30] for $E_g(x, T)$ are also listed in Table II. Those obtained from the expression given by Wiley and Dexter,[8] which assumes a linear dependence of energy gap on both composition and temperature, agree well with the experimental values.

## DISCUSSION

According to the $\vec{k}\cdot\vec{p}$ analysis, at 4.2 °K the position of the Fermi level, with respect to the valence band, is independent of pressure in all three samples. It is situated more than 9 meV (or $25kT$) above the conduction-band edge at zero pressure. This must be reconciled with hole concentrations greater than $10^{17}$ cm$^{-3}$ which are measured in samples 7B1 and 8B at 4.2 °K. The high values for the $np$ product cannot be due to an overlap of the conduction and valence bands, since the high hole density is not observed in sample 7B.

A possible model to account for the observed behavior is shown in Fig. 11. The energy-band structure near the zone center is shown as a function of pressure for an alloy which is semimetallic at zero pressure. We show an acceptor level situated above the heavy-mass valence-band edge, whose energy with respect to the valence-band edge does not change with pressure. Thus, below the pressure $P_c$ the acceptor states lie within the conduction band. Evidence for discrete impurity states lying within a band of states has been obtained in other materials. In CdTe the

TABLE II. Values at 4.2 and 77 °K for the energy gap at zero pressure and the Fermi energy.

| Sample | $T$ (°K) | $x$ | $E_F$ (meV) | $E_0$ (meV) | $E_0$ calculated (meV) (Ref. 8) | (Ref. 30) |
|---|---|---|---|---|---|---|
| 7B | 4.2 | 0.149 ± 0.005 | 9 | −16 | −14 ± 9 | −45 ± 9 |
| 7B1 | 4.2 | 0.149 ± 0.005 | 16 | −10 | −14 ± 9 | −45 ± 9 |
| 8B | 4.2 | 0.138 ± 0.005 | 20 | −33 | −35 ± 9 | −63 ± 9 |
| 7B | 77 | 0.149 ± 0.005 | 23[a] | −8.0 | +11.6 | −15 |
| | | | 31[b] | +2.0 | +11.6 | −15 |

[a]Calculated assuming a hole mass $m_h^* = 0.3$

[b]Hole mass $m_h^* = 0.7$.