whole composition range by assuming almost constant $F$ and Levin *et al.*[19] discussed dilute Ni region. The latter authors have pointed out the appropriateness of decreasing $F$ with $c$. For Ni-Pt, on the other hand, Schindler[20] has investigated on the basis of uniform enhancement model, in which Pt as well as Ni is attributable to $T_c$ and $U_{eff}$ may be the weighted mean with $c$ of those of Ni and Pt. Also this alloy has been considered as homogeneous one[21] and above statements may be accepted. Ni-Rh: Levin *et al.*[19] have pointed that uniform enhancement model may be applied to dilute Ni region. With respect to $F$, $F(c)$ is not monotonic, but will take maximum judging from the state density of Ni and Rh,[19] since Rh has one less electron than Ni.

### 3.2 *Pressure effects on $T_c$, $\Delta T_c/\Delta p$*

The pressure effects on $T_c$, $\Delta T_c/\Delta p$, obtained for the alloys are shown in Fig. 4 as a function of solute concentration $c$. Because $T_c$ changed linearly with applied pressure in the pressure range presently employed, $\Delta T_c/\Delta p$ could be determined uniquely from the slope of $T_c$ vs pressure curve.

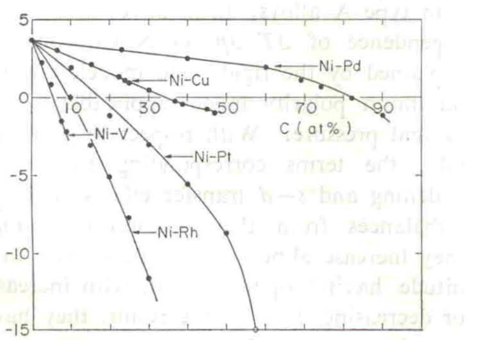


Fig. 4. A plot of the pressure effects on $T_c$, $\Delta T_c/\Delta p$, as a function of solute concentration $c$.

The experimental results shown in Fig. 4 are arranged as follows: (i) For all the alloys, $\Delta T_c/\Delta p$ decreases with increasing $c$. The initial rate of decrease is largest for Ni-V and smallest for Ni-Pd alloys, likewise the case of $T_c$ at normal pressure in Fig. 3. (ii) For each alloy, $\Delta T_c/\Delta p$ changes the sign from positive in Ni rich region to negative as $c$ increases. The reduced solute concentrations to $c_F$, $c/c_F$'s, where $\Delta T_c/\Delta p$ changes the sign are about 0.3 for Ni-Pt and -Rh, 0.6 for Ni-V and -Cu, and 0.85 for Ni-Pd alloys. The data on $\Delta T_c/\Delta p$ near $c_F$ have been obtained for Ni-Pd by Beille[22] and -Pt by Alberts *et al.*[21] and only the result for $Ni_{42.9}Pt_{57.1}$ is plotted in Fig. 3, since the behavior near $c_F$ is not the main object in the present work. (iii) For Ni-V and -Cu alloys, $\Delta T_c/\Delta p$'s change almost linear. For the others, curves are concave downward. Among them, the variation of the curve is rapid near $c_F$ for Ni-Pt and -Rh alloys. (iv) Unlike the case at normal pressure, no coincidence of the curves has been obtained for Ni-Cu and -Pt alloys. This result suggests[7] that the data on $\Delta T_c/\Delta p$ will play a part to the classification of characteristics of alloys at normal pressure.

In the current investigation of $\Delta T_c/\Delta p$ derived from $T_c$ in eq. (1), the following conditions have been assumed: (i) The band width $W$ of the $d$-band depends on the Heine's relation,[23] $W \propto R^{-5}$, where $R$ is the interatomic distance. (ii) The $d$-band is widened uniformly with pressure. (iii) The effective correlation energy $U_{eff}$ employed is the Kanamori type[24]

$$U_{eff}=\frac{U_b}{1+U_bK}\,, \qquad (2)$$

where $U_b$ is coulomb self-energy of an atomic orbital and $K$ is a quantity depending on the band shape.

Besides these assumptions proposed by L.E. for the analysis of $\Delta T_c/\Delta p$ of Ni and Ni-Cu alloys, L.E. have also introduced the compression-induced conduction band effect ($s-d$ transfer). The expression for $\Delta T_c/\Delta p$ derived by them is

$$\frac{\mathrm{d}T_c}{\mathrm{d}p}=\frac{5}{3}\kappa T_c+(\xi_1'+\xi_2+\xi_3)\frac{5}{3}\kappa T_c\,, \qquad (3)$$

where $\kappa$ is the volume compressibility of the material. In eq. (3), the 1st term $(5/3)\kappa T_c$ corresponds to a simple case of $d$-band widening in which $U_{eff}$ is infinite and the effect of $s$-band is neglected. The term $\xi_1'$ is the contribution of the $d$-band in case of $U_{eff}$ being finite, referred to as $d$-band widening in the present paper, and $\xi_2+\xi_3$ come from the $s-d$ transfer with compression. The term $\xi_2$ in eq. (3), however, has not been considered here, since L.E. have pointed that this term is never of primary importance.

Comparing eq. (3) with the expression obtained by Shiga,[4] who has investigated $\Delta T_c/\Delta p$ of Invars without considering $s-d$ transfer, eq. (3) can be written as

$$\frac{\mathrm{d}T_c}{\mathrm{d}p}=\frac{5}{3}\kappa T_c+\frac{D}{T_c} \qquad (4a)$$

$$D=\frac{\kappa}{2k^2\alpha}\left[-\frac{5}{3}\frac{U_{\rm eff}}{U_{\rm b}}+\frac{N_{\rm c}}{\tilde{F}+F_{\rm c}}\left(\frac{F_s}{F}-K_s U_{\rm eff}\right)0.36\right], \qquad (4b)$$

where $k$ is the Boltzmann's constant and notations $N_c$, $F_c$, $F_s$, $\tilde{F}$ and $K_s$ are referred to the article of L.E., and $\alpha$ to Shiga. It is understandable that (i) from eq. (4a), $\Delta T_c/\Delta p$ consists of two terms which are proportional and inversely proportional to $T_c$ at first sight, (ii) in eq. (4b), the 1st and 2nd terms in the brackets in $D$ are functions of $F$ and $U_b$ or $F$ and $U_{\rm eff}$, where $K$ acts through $F$, and correspond to $\xi_1'$ ($d$-band widening) and $\xi_3$ ($s-d$ transfer) terms in eq. (3), respectively. Shiga's expression is the sum of $(5/3)\kappa T_c$ and the 1st term in $D$.

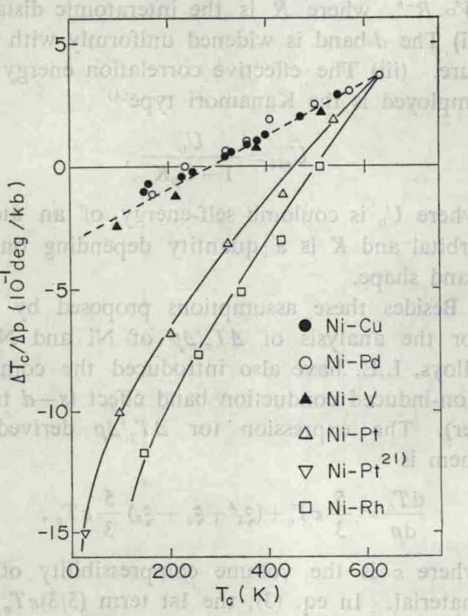


Fig. 5. A plot of $\Delta T_c/\Delta p$ as a function of $T_c$.

On the basis of considerations mentioned above, results for $\Delta T_c/\Delta p$ plotting as a function of $T_c$ will bear a rather profound meaning than plotting as a function of $c$ such as shown in Fig. 4. Figure 5 thus shows $\Delta T_c/\Delta p$ as a function of $T_c$. It is to be noted that the functional forms of $\Delta T_c/\Delta p$ in Fig. 5 are classified into two types, A and B. In type A, the linearity of $\Delta T_c/\Delta p$ with $T_c$ almost holds. Ni-V, -Cu and -Pd alloys belong to this type and the data almost lie on a line expressed as $\Delta T_c/\Delta p = (5/3)\kappa T_c - 3\times10^{-1}$ in unit of deg/kb, using the compressibility $\kappa$ of Ni at room temperature.[25] The concentration and temperature dependence of $\kappa$ for the alloys may be neglected for the present purpose, judging from the experimental results.[25,26] For Ni-Pd, the deviation from the linearity near $c_F$ has been reported,[22] but the behavior near $c_F$ is not the main object in the present paper as is mentioned above. In type B alloys, on the other hand, $\Delta T_c/\Delta p$ vs $T_c$ curve is not linear, concave downward from Ni rich side. Ni-Pt and -Rh alloys belong to this type. In other words, type A or B is that in which the 2nd term $D/T_c$ in eq. (4a) is constant independent of $T_c$ or $c$, or a function of $T_c$ or of $c$.

These results will be discussed qualitatively on the basis of the following standpoints: (i) The descrimination between type A and type B might be made essentially from the dependence of $F$ and $U_b$ on $T_c$ or from the degree of contribution of the $d$-band widening and the $s-d$ transfer effects to $D$. (ii) The results obtained by Lang[27] and L.E. that $D$ shifts to the negative side regardless of its sign when $F$ and $U_b$ decreases, may be accepted as general tendency and applied to the alloys presently concerned, as far as discussions will be made from eq. (4a) and (4b).

In type A alloys, L.E. have pointed that $c$ dependence of $\Delta T_c/\Delta p$ for Ni-Cu could not be explained by the rigid band model, but by the minimum polarity model applicable to $T_c(c)$ at normal pressure. With respect to $D/T_c$ in eq. (4b), the terms corresponding to the $d$-band widening and $s-d$ transfer effects almost counterbalances from their numerical results that they increase almost in the same way in magnitude having opposite sign, with increasing $c$, or decreasing $T_c$. As the result, they have obtained constant $D/T_c$.

Above mentioned results for Ni-Cu obtained by L.E. could not be applied unconditionally to Ni-V and -Pd alloys belonging to type A, since the appropriate models and the detailed band shapes etc. are necessary to the final estimation. However, since the situation of $F(c)$ and $U_{\rm eff}(c)$ for Ni-V would be similar to Ni-Cu as described in § 3.1, the competition between the widening and the transfer terms in Ni-V would vary as $c$ in a similar way to Ni-Cu. On the other hand, the simple argument unlikely explain the data on Ni-Pd, but the experimental results will support the similar situation.

For type B alloys, the competition between the widening and the transfer in $D/T_c$ should