



FIG. 33. (a) Grüneisen constant,  $\gamma_G$ , as calculated from  $C_v^t$ , of the rare-earth metals. (b) Size factor of the rare-earth metals. Open points are estimated data.

poor (Be, C(g), Si, Mn, Co, Ge, Rb, Zr, Ru, Pd, Ag, La, Ce( $\gamma$ ), Lu, Ta, W, Ir, Pt, Bi, and U). Of the elements which are included in the "poor" category, the compressibility data for 8 of the metals (Ru, Pd, Ag,  $\gamma$ -Ce, W, Ir, Pt, and U) was suspected of being incorrect (see Section 24). The compressibility data of Mn and Rb had been questioned by Gilvarry,<sup>17</sup> and this may explain the poor agreement for these two elements. If these elements are excluded from the above analysis, then we would have 18 very good, 11 good, 11 fair, and 10 poor. Thus it would appear that one finds reasonable agreement between  $\gamma_G$  and  $\gamma_S$ , as had been proposed by Slater.

The mean value for  $\gamma_S$  was found to be  $1.64 \pm 0.91$ , if the value for the elements Ru, Ag,  $\gamma$ -Ce, Pd, and W are excluded from the average. The error  $\pm 0.91$  corresponds to the percentage error of  $\pm 55.5$ , which is slightly poorer than that for  $\gamma_G$ .

*Grüneisen Constant  $\gamma_{SW}$ .* The Grüneisen constant as determined from shock wave data,  $\gamma_{SW}$ , was also compared with  $\gamma_G$ . It was found that  $\gamma_{SW}$  was smaller than  $\gamma_G$  for 17 elements and greater for 9 elements (almost 2 to 1). By using the same criteria as given above, it was found that very good agreement was obtained for 22 elements (Be, Na, Mg, Ti, V, Co, Ni, Cu, Zn, Zr, Nb, Mo, Rh, Pd, Ag, Cd, In, Sn(w), W, Tl, Pb, and Th); good agreement for 3 elements (Cr, Pt, and Au); and poor agreement only for tantalum. This indicates that  $\gamma_G = \gamma_{SW}$  is a very good approximation.

Since the agreement between  $\gamma_G$  and  $\gamma_{SW}$  is good for Be, Co, and Zr (3 of the 10 remaining elements for which  $\gamma_S$  is in poor agreement with  $\gamma_G$ ), this places a higher degree of confidence on  $\gamma_G$  for these 3 elements and therefore suggests that  $\gamma_S$  may be unreliable because of inaccuracy in the compressibility data, especially in the  $b$  (pressure-dependence) term.

It is interesting to find that  $\gamma_{SW} \approx \gamma_S$  for tantalum and that both of these values are very much smaller than  $\gamma_G$ . Perhaps the value for  $\gamma_G$  is incorrect, although this seems unlikely since the values of  $\alpha$ ,  $V$ ,  $\chi$ , and  $C_v$  are reasonably well established.

The mean value for  $\gamma_{SW}$  is 1.76, which is somewhat larger than the mean value of  $\gamma_G$ , 1.57. Since it was mentioned above that  $\gamma_{SW}$  is usually smaller than  $\gamma_G$ , the reverse relationship between the means is somewhat surprising. However, if one takes the average for the same elements for which  $\gamma_G$ ,  $\gamma_S$ , and  $\gamma_{SW}$  are all known (Be, Mg, Al, Ti, V, Cr, Co, Ni, Cu, Zn, Zr, Nb, Mo, Rh, Cd, In, Sn(w), Ta, Pt, Au, Tl, Pb, and Th), we find the mean values to be 1.98, 1.67, and 1.76, respectively.

Gschneidner and Vineyard<sup>4</sup> have used the Grüneisen constant to predict departures from Vegard's law (which states that the lattice constants of binary alloys vary linearly between the two end-members). They found that their method, based on second-order elasticity, described the sign and order of magnitude of departures from Vegard's law in binary alloy systems better than did previous techniques given in the literature.

*Estimated Data.* In calculating  $\gamma_G$  from  $C_v^t$  and  $C_v$ , there are a few elements for which the coefficient of expansion, the compressibility, or the heat capacity at constant volume ( $C_v^t$  and  $C_v$ ) were not known experimentally. If any one of these quantities was estimated, then  $\gamma_G$  was considered to be estimated also.

## 29. SIZE FACTOR

*Eshelby's Approach.* Eshelby<sup>118</sup> has pointed out in his review paper on the continuum theory of lattice defects that it is possible to derive

<sup>118</sup> J. D. Eshelby, *Solid State Phys.* **3**, 79 (1956).