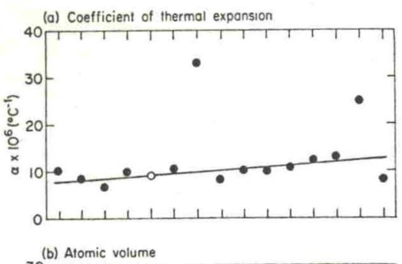

FIG. 10. (a) Linear coefficient of thermal expansion of the rare-earth metals. (b) Atomic volume of the rare-earth metals. Open points are estimated values.

bismuth. The anomalous behavior of manganese is evident. The variation of the coefficient of expansion with atomic number for the rare earths (Fig. 10a) is quite normal. The large values for europium and ytterbium are, as noted earlier, a manifestation of their divalent character as opposed to the normally trivalent rare earths.[13]

Chromium. The literature value given for the coefficient of thermal expansion of chromium is about 3×10^{-6}(°C^{-1}) at 298°K (25°C). Because of the paramagnetic–antiferromagnetic transition at about 310°K (37°C), this coefficient is much lower in the region between about 290°K and 330°K (17°C and 57°C) than it is below 280°K (7°C) and above 340°K (67°C). In order to obtain a value which is not affected by this magnetic ordering, the values of the coefficient of thermal expansion well below the magnetic transition temperature have been connected by a straight line with those well above this transition in a plot of the coefficient of thermal expansion versus the temperature. The coefficient of expansion given in this review was estimated from the interpolated line at 298°K. It is noted that this value is almost three times as large as the experimentally determined value. The reviewer, however, believes that it is more representative of chromium when one is not concerned with its magnetic properties.

Examination of the elastic properties given by Bolef and de Klerk[39] indicates that these properties are only slightly affected (about 3% at the most) by the magnetic transition in chromium. This is compared with a factor of about 3 for the thermal expansion coefficient. Because of the small variation of the elastic properties, no attempt was made to correct them for this magnetic transition.

Gadolinium. As does chromium, gadolinium undergoes a magnetic transition near room temperature. At 289°K (16°C) gadolinium undergoes a paramagnetic–ferromagnetic transition. Because of the strong influence of magnetic transitions on the coefficient of thermal expansion, the X-ray value given by Spedding *et al.*[40] at 361°K (88°C) is considered to be representative of the coefficient of expansion of gadolinium at 298°K (25°C) uninfluenced by the magnetic transition.

Estimated Data. Most of the estimated values of the coefficient of thermal expansion are based on the relationship between the coefficient and the melting point (see Section 25). The product of the coefficient of expansion, α, and the melting point, T, for red phosphorus is assumed to be the same as it is for white phosphorus ($\alpha T = 0.0395$); for monoclinic sulfur, the same as rhombic sulfur (0.0248); for technetium, radium, and actinium, the same as the average value for the face-centered cubic, body-centered cubic, and hexagonal closest-packed metals (0.0197); and for protactinium, the same as the mean for gallium, indium, white tin, mercury, and uranium (0.0123). The product of α and T for the alkali metals increases with increasing atomic number, and for that reason the value of αT for francium (0.0304) was obtained by extrapolation from the values for lower-atomic-number alkali metals. By using this value of αT the coefficient of expansion is estimated to be 102×10^{-6} (°C^{-1}). The value for promethium was estimated from the straight line in a plot of the coefficient of expansion versus the atomic number of the rare-earth metals (Fig. 10a).

[39] D. I. Bolef and J. de Klerk, *Phys. Rev.* **129,** 1063 (1963).

[40] F. H. Spedding, J. J. Hanak, and A. H. Daane, *J. Less-Common Metals* **3,** 110 (1961).