

cerium (see below), ytterbium, and thorium; the complex crystal-structure forms designated as  $\alpha$ -Mn,  $\alpha$ -U,  $\alpha$ -Np, and  $\alpha$ -Pu; the body-centered cubic ( $A2$ )<sup>6a</sup> form of iron ( $\alpha$ -Fe); the hexagonal (with a double  $c$ -axis) form of lanthanum, praseodymium, and neodymium; the rhombohedral form of mercury and samarium; and the simple cubic form of polonium. The remaining elements, except phosphorus and tin (see below), are known to have only one crystalline modification. The data for mercury are for the solid at its melting point of 234°K ( $-39^\circ\text{C}$ ) instead of 298°K. Some of the properties, such as the melting point, heat of fusion, boiling point, etc., obviously do not pertain to this temperature, or to the allotrope which exists at 298°K.

For five of the elements, viz., carbon, phosphorus, sulfur, tin, and cerium, data are given for more than one allotrope. In the tables, the following nomenclature is used to identify the various allotropes of these five elements: C(g) refers to graphite, which is the standard reference state at 298°K; C(d) refers to diamond; P(w) refers to white phosphorus; P(r) refers to red phosphorus, which is the standard reference state at 298°K; P(b) refers to black phosphorus; S(r) refers to orthorhombic sulfur, commonly called "rhombic" sulfur, which is the standard reference state at 298°K; S(m) refers to monoclinic sulfur; Sn(w) refers to white or metallic tin, which is the standard reference state at 298°K; Sn(g) refers to gray or diamond tin; Ce( $\alpha$ ) refers to the collapsed face-centered cubic form of cerium, which exists below 116°K at 1 atm, or above 7470 atm at 298°K; and Ce( $\gamma$ ) refers to the normal face-centered cubic form of cerium, which is the standard reference state at 298°K.

A list of references is given for each table, so one does not have to thumb back and forth to find the source of information. In some instances where no experimental data exist, an estimated value is given. The estimated value is always given in parentheses, and the manner in which the value was derived is discussed in the text.

## 2. GENERAL DESCRIPTION OF THE DERIVED PROPERTIES

The derived properties and some interrelationships of the physical properties are examined and discussed in Part IX of this chapter. Those subjects which also appear in tabulated form are listed in the accompanying tabulation.

The initial goal in our alloy-theory program was a set of Grüneisen constants<sup>4</sup> and a set of size factors.<sup>7</sup> In order to calculate these quantities, almost all of the physical properties given herein are needed in the computations. Some of the other derived quantities are not only intermediate

<sup>7</sup> J. T. Waber, A. C. Larson, and K. A. Gschneider, Jr., to be published (1965).

Table number	Table title
XIX	Ratio of Young's Modulus to the Shear Modulus
XX	Ratio of $(1 - \sigma)/(1 + \sigma)$ (where $\sigma$ is Poisson's ratio)
XXI	Ratio of the Compressibility Constants, $b/a^2$
XXII	Leibfried, Modified Leibfried, and Bragg Numbers
XXIII	Entropies of Fusion and Vaporization
XXIV	Grüneisen Constant
XXV	Size Factor

steps in the computations of the Grüneisen constant and size factor, but also serve as checks on the consistency of initial data (i.e., the measured physical properties of the elements). Furthermore, some of the "constants" of the elements—i.e., the Grüneisen constant, entropy of fusion, etc., which have been derived for a few elements and then generally assumed to apply to all elements—are examined to see if this generalization is valid. No attempt is made to discuss these properties in detail, since most of them are discussed in textbooks and in many instances in detailed review papers recently published.

## II. Elastic Properties

The four elastic properties listed here, Young's (elastic) modulus, the shear modulus, Poisson's ratio, and the compressibility, are for bulk, polycrystalline materials. At the time of writing, single-crystal elastic constants were available for about half of the elements considered herein. It is because of this sparsity of data that single-crystal values are not included in this review. Hearmon<sup>8,9</sup> and Huntington<sup>10</sup> have included in their review papers extensive listings of elastic constants derived from single crystals. Almost all of the more recent single-crystal data (since 1957–1958) have generally been published in either the *Physical Review* or the *Journal of Applied Physics*.

In a few instances where reliable polycrystalline data are lacking but single-crystal data are available, the reviewer has used the method of Voigt<sup>11</sup> to calculate the four elastic properties from the single-crystal data. Values so obtained are identified as such in the tables.

<sup>8</sup> R. F. S. Hearmon, *Rev. Mod. Phys.* **18**, 409 (1946).

<sup>9</sup> R. F. S. Hearmon, *Advan. Phys.* **5**, 323 (1956).

<sup>10</sup> H. B. Huntington, *Solid State Phys.* **7**, 213 (1958).

<sup>11</sup> W. Voigt, "Lehrbuch der Kristallphysik," Teubner, Leipzig, 1928; also see Huntington,<sup>10</sup> p. 317.