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COMPRESSIBILITY OF CERIUM UP TO 30,000 kg/cm^2

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The pressure dependence of the volume decrement is found for two modifications of cerium, α-Ce and γ-Ce, by the "piston displacement" method and by x-ray diffraction. It is shown that the compressiblity of the gamma modification increases with pressure. By removing the pressure at a very gradual rate it is possible, at atmospheric pressure, to obtain the alpha modification with a lattice constant a_0 = 4.94 A.

A large number of papers on the compression of cerium have been concerned with explaining two interesting characteristics of this element, namely the possible existence of a critical point on the equilibrium curve in the $\alpha \rightleftarrows \gamma$ phase diagram and the anomalous behavior exhibited by the pressure dependence of the γ-Ce compressibility.

Bridgman found that at room temperature cerium undergoes a polymorphic transformation at pressures of about 7000 kg/cm^2 with an appreciable discontinuity in volume [1, 2]; he discovered when this happened that the compressibility of the γ-Ce low-pressure phase increased with pressure up to the transition point [2], which is an anomaly. The α-Ce high pressure phase behaves normally, i.e., its compressibility decreases with increasing pressure. Later it was demonstrated that this transformation is an isomorphic transition from the normal fcc phase to a phase with a collapsed fcc structure, where the lattice constant of the latter is a = 4.84 ± 0.03 A at 15,000 kg/cm^2 [3]. An investigation of the phase diagram for cerium under pressure has established that the same transformation can be observed at atmospheric pressure in the low temperature region [4-6].

The special nature of this transformation, including the preservation of symmetry by the crystal lattice and the reduction in volume changes, heating effect, and changes in resistivity with increasing temperature and pressure of transition, has suggested the existence of a critical point on the $\alpha \rightleftarrows \gamma$ conversion curve [7-10]. However, in one of the more recent investigations devoted to the phase diagram of cerium it was shown that, although possible, such an occurrence is only faintly probable [11]. We note also that the cause of the $\alpha \rightleftarrows \gamma$ transition is assumed to be rearrangement of the outer electron levels, with one of the 4f-electrons going over to the 5d valence level [3]. This result was also confirmed by neutronographic investigation of the $\alpha \rightleftarrows \gamma$ transformation [12].

Considerably less attention has been devoted to the anomalous compressibility of γ-Ce. Bridgman's data, which he obtained in different years, imply inversion of the pressure dependences of the bulk compressibility of cerium [1, 13, 14].

Apart from Bridgman's work [1, 14], this anomalous behavior of γ-Ce has been further evidenced in x-ray studies at 15,000 kg/cm^2 [3] and ultrasonic measurements of the elastic moduli up to pressures of 10,000 kg/cm^2 [15].

The present paper is devoted to a study of the anomalous compressibility of gamma cerium using two alternative methods: the so-called "piston displacement" method and a method involving x-ray diffraction.

The apparatus used for the decrements ($\Delta V/V_0$) has been described in detail in earlier papers [8, 16]. The cerium sample* was compressed in a piezometer with lead used as the compressive medium. In the region of polymorphic transition we encountered certain difficulties in processing the data for the curve of "piston displacement vs. applied force" $\Delta l(F)$ insofar as the transition takes place in a certain pressure interval and is completed at

*The samples were fabricated from material having the following impurities: Nd < 0.75%; Pr < 0.75%, Fe < 0.002%, Cd, Pb, Bi, Si < 10^{-3}%.