ing theoretical assumptions.

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PECULIARITIES OF SHOCK COMPRESSION OF LANTHANIDES

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As is well known, successive rearrangement of the 4f-electron subgroup takes place in rare-earth elements with increasing atomic number.

Inasmuch as the filling of the outer electron shells remains unchanged at the same time, the physico-chemical properties of rare metals are quite similar. In particular, they have space lattices constituting different variants of closest packing.

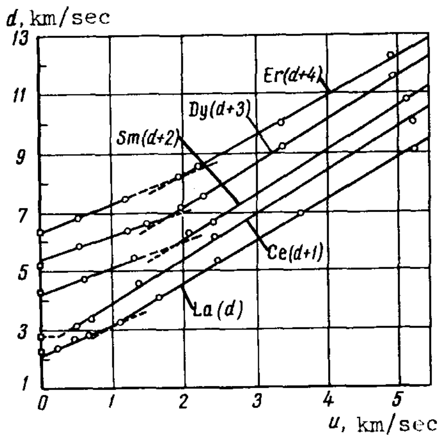
The appearance of denser phases upon compression of such structures, or a reduction in compressibility, is evidence of a change in the electron distributions.

The rearrangement of the electronic structure has been observed for lanthanides only in the case of cerium [1] at static pressures of 12 kbar. According to Hume-Rothery and Raynor [2], a variant of the transition of 4f-electrons to the 5d-band is realized in this case, and results in the appearance of a strong covalent bond, which increases the density of the metal.

In this communication we report the first results of an investigation of the dynamic compressibility of five lanthanides, La, Ce, Sm, Dy, and Er, up to 3.5 Mbar pressure.

The shock-compression parameters were obtained by the reflection method [2,4] using the experimental apparatus of [5,6], where shock waves of fixed intensity were produced in screens covering the samples.

The directly-measured quantities were the velocities d of the shock waves in the investigated metals. These quantities were used to determine, with the aid of the conservation laws



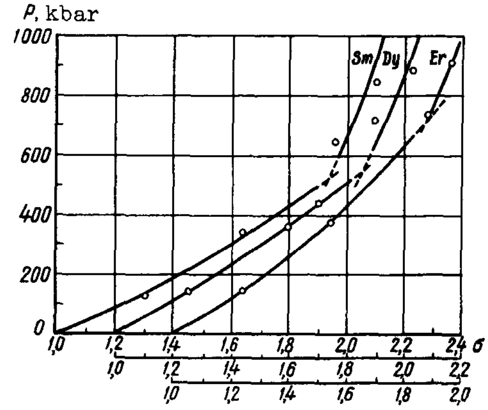


Fig. 1. d-u plots for five lanthanides. Squares - initial speed of sound c_0, calculated from the adiabatic compressibility coefficient taken from [7]; circles - experimental points of present work; dashed - extrapolated sections of d-u plots.

Fig. 2. P-σ plot of three lanthanides, $\sigma = \rho/\rho_0$.

and the conditions on the screen-sample boundary, the mass velocities u, the shock-compression pressures $P = \rho_0 du$ (ρ_0 = initial density of the sample), and the degrees of compression $\sigma = \rho/\rho_0 = d/(d - u)$. The d-u diagrams of the elements, plotted from the experimental data, are shown in Fig. 1. The d-u plot of each of the lanthanides is described with high accuracy by two straight-line segments having different slopes.

The parameters of the equations

$$d = c_{01} + \lambda_1 u; \quad d = c_{02} + \lambda_2 u \tag{1}$$

of these segments, as well as the coordinates of their intersection points, are listed in the table.

Parameters of d-u diagrams of lanthanides

Element	c_{01}, km/sec	λ_1	c_{02}, km/sec	λ_2
La, ρ_0 = 6.15 g/cm^3	2.08	1.064	1.66	1.45
Ce, ρ_0 = 6.63 g/cm^3	-	-	1.38	1.51
Sm, ρ_0 = 7.50 g/cm^3	2.22	0.870	1.00	1.531
Dy, ρ_0 = 8.52 g/cm^3	2.36	0.810	1.17	1.497
Er, ρ_0 = 9.05 g/cm^3	2.31	0.96	1.50	1.368

The linear character of the d-u relations allows us to express the upper and lower branches of the adiabats in P-σ coordinates by means of relations of the type

$$P = \frac{\rho_0 c_0^2(\sigma - 1)\sigma}{(\lambda - 1)^2\{[\lambda/(\lambda - 1)] - \sigma\}^2} . \tag{2}$$

For the three lanthanides (Sm, Dy, Er) for which the kink is most pronounced, we plotted with the aid of (1) and (2) the shock adiabats up to 1 Mbar, as shown in Fig. 2.

In all the previously investigated metals [3,5,8,9], the d-u plots were either straight lines (Ni, Mo), or slightly bent curves of decreasing slope. For the lanthanides, to the contrary, the right-hand segments of the curves, which are practically parallel to one another, have slopes that greatly exceed those of the left-hand sections. For cerium, whose electronic transition takes place, according to [1], at low pressure, the "right" branch of the adiabat covers practically the entire investigated pressure range. The kink of the shock-compression curve is observed at 220 kbar for lanthanum and in the pressure interval 590 - 740 kbar for samarium, dysprosium, and erbium.

For most investigated lanthanides, the detailed behavior of the curves near the critical pressures has not yet been determined. Judging from lanthanum and dysprosium, the kink in the compression curves, observed as the volumes are continuously varied, is of the same type as in second-order phase transitions.

The gently-sloping sections of the adiabats are probably determined by the compression of the external low-density 6S shells, and by the simultaneously occurring redistribution of the electrons among the bands. In this case the kinks of the adiabats can be explained as signifying the completion of these processes and the formation of low-compressibility electronic configurations. A more complete and unambiguous interpretation of the obtained experimental data calls for calculation of the energy spectra of compressed metals, for example by the method of Gandel'man [10,11].

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