Shock compressibility of lead, quartzite, aluminum, and water at a pressure of ~100 Mbar

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Experimental results of shock compressibility of Pb, SiO_2, Al, and H_2O, which indicate that the thermodynamic properties of matter depend noticeably on the shell structure of the atom, were obtained.

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The equations of state of matter, which are essential for a numerical modeling of processes characterized by a high concentration of energy, are derived from different theoretical models. The statistical model of the atom in its original form (Fermi-Thomas model)[1] and with quantum and exchange corrections (FTC model)[2,3] is widely used for this purpose. The main disadvantage of the statistical model is that it does not take into account the shell structure of the atom, which leads to an oscillatory dependence of the thermodynamic characteristics of matter on Z, ρ, and T. There is no reliable standard theoretical information that takes such properties into account. The data obtained from different models[4–6] disagree within the limits of the investigated effect. The experiment proposed by us makes it possible to obtain data for shock compressibility of matter at record pressures of ~100 Mbar, which exceed those achieved by Trunin *et al.*[7] by approximately a factor of 2.

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Sample	Lead	Quartzite	Aluminium	Water
$\rho_0 \left(\frac{g}{cm^3}\right)$	11.35	2.65	2.70	1.022
P (Mbar)	158	70	55	32
t_{calc} (nsec)	1962	1344	1349	1155
t_{exp} (nsec)	1596	1047	1546	1143

The data for shock compressibility were obtained in our experiments on the basis of the well-known reflection method.[8] The experimental setup, which was subjected to similar conditions as those for the measurements in Refs. 7 and 9, consisted of a standard steel plate that supported the samples. A plane shock wave was excited in the standard. The measurements involved the recording of arrival of a shock wave at the control surfaces of the plate and the samples. The airglow produced during arrival of the shock wave at the surface was recorded by photovoltaic cells. The accuracy of measurement of the time intervals was better than 1%. The shock adiabatic curves for

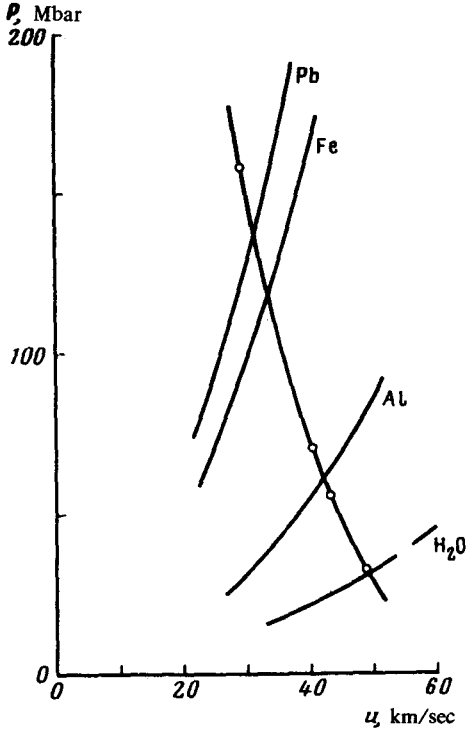

FIG. 1. A comparison of the experimental results for shock compressibility with the calculated shock adiabatic curves according to FTC (the calculated shock adiabatic curves for Al almost coincide with those for SiO_2). The ellipses represent the experimental data, taking into account the measurement errors of the wave velocities.

a single and double compression and also the isentropes for the discharge of iron, which are necessary for interpretation of the measurement results, were calculated by using the data of the FTC model. One of the samples was prepared from the same sample as the standard. This made it possible to determine experimentally the wave damping due to motion along the standard. The results of evaluation of the experimental data are given in Table I.

The initial state in the standard is $u = 33.3$ km/sec; $P = 119.9$ Mbar.

Figure 1 shows the shock adiabatic curves calculated from the FTC model and a plot of the obtained experimental points. We can see that only the iron-water pair is consistent with the calculated representations. Such agreement most likely is accidental: since the shell effects depend on Z nonmonotonically, they can be compensated for compounds with different Z at some values of ρ; T and strengthened at other values of ρ; T. This apparently accounts for the distribution of the points for aluminum and quartzite.

The obtained results show that the shell structure of the atom has a noticeable effect on the behavior of shock adiabatic curves in the region of high pressures and that the use of models describing the thermodynamic properties may produce large errors in the calculations of high-intensity, gas-dynamic processes.

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