thermal pressure and the thermal energy was obtained in experiments on the compression of porous samples and by recording their subsequent expansion.

Both lead and other metals, which were not included in the experimental studies, retained high energy states of a strongly nonideal plasma, occupying on the abscissa axis a range of densities covering two orders of magnitude: from hundreths of a gram to several grams.

The experimental study of these states by dynamic methods in their traditional and modified variants, as well as the construction of adequate theoretical models for them, is one of the basic directions of research in the physics of high energy densities.[23]

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V. E. Fortov. *Equation of state of a nonideal plasma for extreme values of the parameters.* The thermodynamic properties of thermally ionized plasma can be calculated reliably in limiting cases of ultrahigh temperatures and pressures, when the classical (Debye-Hückel) and quasiclassical (Thomas-Fermi) approximations to the self-consistent field method are applicable.[1] The region of compressed and heated solid and liquid is realized in static[2] and dynamic[3] experiments. In the intermediate region of parameters, between the condensed state and the ideal gas, a dense plasma with strong interparticle interaction arises, and this impedes the use of theoretical methods[4] and urgently requires experimental studies.[5,6]

Two basic modifications of dynamic methods are used to study an ideal plasma experimentally[3–5]: shock-wave or adiabatic compression of inert gases and vapors of alkali metals, as well as adiabatic expansion of metals which are precompressed and preheated by strong shock waves. The experiments on shock-wave compression of dense inert gases (the initial state (1) in Fig. 1) made it possible to obtain plasma under high pressures $P \lesssim 180$ kbar and at high temperatures $T \lesssim 10^5$ K, where fully developed ionization $n_e \lesssim 10^{23}$ cw^{-3} is realized with densities of up to 4.5 g/cm^3, exceeding by a factor of 1.5 the crystallographic density of xenon.[8]

Under these conditions the plasma nonideality parameter

$$\Gamma = \frac{e^2 k\rho}{kT} = \frac{4\pi e^3 n_e^{1/2}}{(kT)^{3/2}},$$

reaches 10, and the electron gas is nearly degenerate:

$$n_e \lambda_e^3 = n_e \left(\frac{\hbar^2}{2\pi m k T}\right)^{3/2} \sim 0.6.$$

This region of parameters was studied with the help of linear explosive shock tubes and explosive projectile devices as a result of both single compression (state 2 in Fig. 1) and twofold compression and with the use of the effects of shaping (state 3). Under these conditions it is possible to measure the caloric and thermal equations of state, the electrical conductivity, and the coefficients of absorption and reflection of visible light from the shock-compressed plasma.[5,6] It is im-

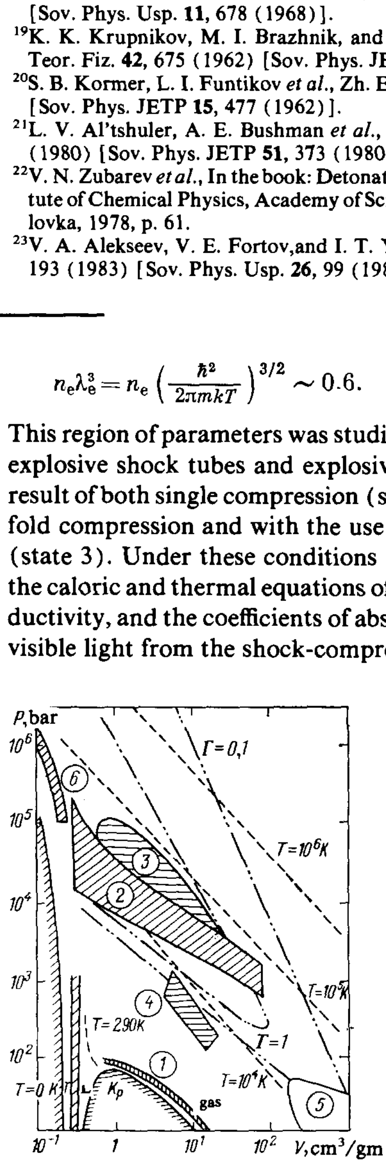

FIG. 1. Phase diagram of xenon. T, K—cold-compression curve, K_p is the critical point. The dashed curves are the isotherms and the dot-dashed curves are curves of constant degree of nonideality Γ. the remaining notation is deifned in the text.

portant that at low densities the region of parameters adjoins the states obtained by compression of xenon in adiabatic (region 4)[7] and pneumatic shock tubes (region 5), while at high densities the region of parameters adjoins the data on the shock-wave compression of liquid xenon in light-gas cannons (region 6).[8]

The thermodynamic measurements performed indicate that the compressibility of the nonideal plasma with supercritical density decreases substantially, which is a result of the deformation of the energy levels of the atoms and ions in a dense disordered medium.[9] This effect was described using the "finite" atom model, which is a combination of the hard-sphere model of a liquid and the ionization model of a plasma.[9] In this model the effect of the medium on the electrons in the atoms and ions was described by the effective potential

$$U(r)=\begin{cases} -\frac{Ze^2}{r}, & r<r_c, \\ \infty, & r>r_c, \end{cases}$$

which was used to calculate the wave functions and eigenenergies by the Hartree-Fock method. The contribution of the translational degrees of freedom was described by the hard-sphere model using the results of molecular-dynamics calculations. The equilibrium value of the radius of the sphere r_c was found by a variational procedure, which made the model thermodynamically closed. The model constructed not only reproduces the thermodynamic features of the dense plasma, but it also describes the "bleaching" of the plasma as it is compressed.[5,6] We note that the necessity of taking into account the discrete spectrum also follows unequivocally from experiments on the shock-compression of liquid xenon and argon,[8] where this effect was described using theoretical models similar to those in Ref. 9.

The results of the measurements of the adiabatic expansion of shock-compressed metals[10] make possible experimental studies of a wide region of the phase diagram of a nonideal plasma: from the strongly compressed condensed state up to the ideal gas, including the region of the metal-insulator transition and the high-temperature boiling curve near the critical point. These data form the basis for the construction of wide-range semiempirical equations of state of matter,[10] required for hydrodynamic calculations of pulsed energy releases. Measurements of the unloading adiabats, as well as data on shock-wave compression, do not indicate unequivocally the existence in the range of parameters studied of specific plasma phase transitions caused by the strong collective interaction of charges with one another or with neutral particles.

The future prospects for the study of the thermophysical properties of nonideal plasma are linked both to the expansion of the range of materials and the use of new methods for generating strong shock waves, such as electrodynamic cannons and concentrated laser radiation.[11]

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