PTU_2 or TU_2, where T is time parity and U_2 is the operation of flipping of the vortex line. A vortex, whose combined parity PTU_2 is conserved (the so-called v vortex), has a spontaneous electric dipole moment, which is oriented along the axis of the vortex. A w vortex with combined TU_2 symmetry has a spontaneous superfluid current, flowing along the axis.

Calculations show that in the B phase at low pressures the vortex is located in the v state. Experimentally, as the pressure is raised, a first-order phase transition, associated with the restructuring of the core of the vortex, is observed in the rotating B phase. It is not clear into what state the vortex goes in such a transition. Superfluidity is not destroyed in the core of a v vortex in the B phase: the core consists of the A phase and another superfluid phase with ferromagnetically ordered spins of Cooper pairs. This so-called β phase is unstable in a free geometry. It is this phase that is responsible for the observed magnetic moment of the vortices.

Vortices in the A and B phases of ^{3}He are discussed in greater detail in the review articles cited in the references.

[1]M. Krusius, P. J. Hakonen, and J. T. Simola in: Proceedings of the 17th International Conference on Low Temperatures Physics, Physica. Ser. B + C **126**, 22 (1984).
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N. N. Kalitkin, V. B. Leonas, and I. D. Rodionov. *Models of extreme states of matter and their experimental verification.* A quantitative description of physical processes at high temperatures ($\gtrsim 1$ eV) and pressures ($\gtrsim 1$ Mbar) requires knowledge of the thermophysical properties of matter under these conditions. The range of pressures $\lesssim 1$ Mbar is traditionally studied by methods of static and dynamic compression. A large volume of data referring to dense materials has been accumulated, and numerous measurements have been performed in recent years with condensed gases (He, Ar, Kr, Xe, CO, CO_2, N_2, and others).

Unfortunately, reliable measurements cannot yet be obtained for pressures exceeding 1–5 Mbar; for this reason, the high-pressure range is described on the basis of theoretical models.

In gas-dynamic calculations primarily two models are now used. The region of gas densities is described by the model of ionization and chemical equilibrium (MICE),[1] and the solid state range is described by the quantum-statistical model (QSM or its variant TFC).[2] The so-called wide-range equations of state are constructed by "joining" the predictions of these models at intermediate densities and adding the experimental data.

The uniqueness of the properties of chemical elements and compounds can be described correctly on the basis of MICE. At the same time the QSM only gives characteristics which are averaged over the periodic system. Many attempts have therefore been made to construct models of the Hartree-Fock type for compressed matter. Some of them, which turned out to be incorrect, predicted substantial deviations from QSM under superhigh compressions. Realistic models at high pressures are close to QSM, and at moderate pressures they describe qualitatively correctly only individual materials; but none of these models is as yet able to describe the uniqueness of the properties of elements even in just one period of Mendeleev's table.

The difficulties in modern theories are stimulating the development of experimental approaches. The experimentally inaccessible region of cold compression up to pressures of $\sim 10^3$ Mbar can be studied by a nontraditional approach, based on the use of data on scattering of fast beams, which allows the achievement of close approach of atoms characteristic of such pressures.[3] Interaction potentials for practically any combination of atoms and molecules in the range 0.1–20 eV are determined from measurements of the differential and integral scattering cross sections of fast beams at small angles. At the same time, the distances of approach of atoms under a pressure of 100 Mbar correspond to a pair-interaction energy of ~ 5 eV for helium and ~ 20 eV for xenon. Under the assumption that pair interactions of atoms in condensed matter make the dominant contribution, these data enable one to calculate the cold-compression curves by means of summation of pair energies. The possibilities of this approach are illustrated in this report for condensed He and H_2. In principle the study of scattering of van der Waal's clusters, with simultaneous recording of the fragments, enables one to determine the limits of applicability of the additivity approximation and even to take into account nonadditive corrections.[3]

Figures 1 and 2 show some results of calculations performed and a comparison is made with measurements of the cold-compression curves.[4,5]

The calculations using pair potentials were performed

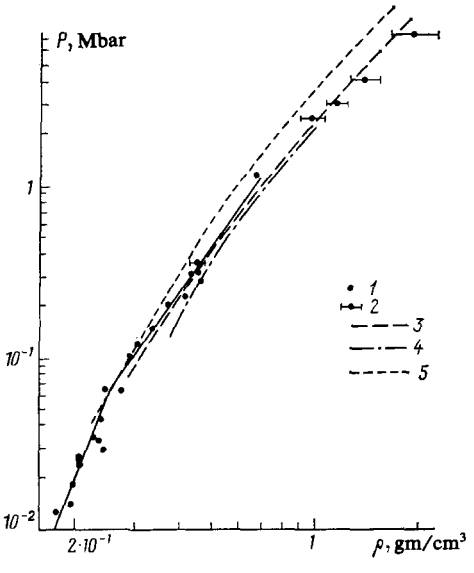

FIG. 1. The cold-compression curve of hydrogen. Experiment: 1) Ref. 4; 2) Ref. 5. Calculations: 3) TFC[2]; 4) QSM[2]; 5) empirical potential.[3] The solid line with the break shows our analysis of the data.[4]

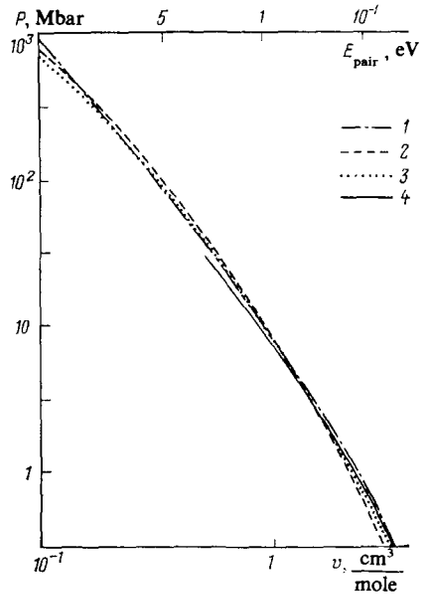

FIG. 2. The cold-compression curves of helium. Calculations: 1) QSM[2]; 2) empirical potential[3]; 3) theoretical potential[7]; 4) effective empirical potential.[6] E_{pair} is the interaction energy per pair of atoms.

for hexagonal close packing (the energy difference between different forms of close packing in the compression range studied is $< 1\%$). Empirical pair potentials, describing the repulsive part of the potential, were used.[3] Because of the short range of the repulsive forces most of the total pressure in the pressure range studied is created by the interaction with the atoms in the first coordination sphere (for He: $\sim 90\%$ at $P \sim 10$ Mbar and $\sim 80\%$ at $P \sim 100$ Mbar). In the calculations illustrated in the figures, summation extended only over the first coordination sphere. The cold-compression curve of He obtained in this manner (see Fig. 2) at pressures $P < 1$ Mbar is in agreement with the data extracted from shock-compression measurements, while in the range up to $P \sim 600$ Mbar the curve agrees with the asymptotic quantum-statistical model of matter. This provides a basis for regarding the truncation of the summation at the first coordination sphere as an efficient method for taking into account the nonadditive corrections for compressions up to pressures of several hundreds of Mbar.

The results of the calculations of the cold compressibility of molecular hydrogen presented in Fig. 1 were obtained using an effective spherically symmetrical potential, reconstructed from the data on the scattering of molecular beams. The more rigid behavior of the cold-compression curve of the molecular phase of hydrogen obtained by the method described above compared to the measurements[5] at pressures $P \gtrsim 3$ Mbar is in agreement with the conclusion drawn in Ref. 5 that a phase transition into the atomic phase occurs

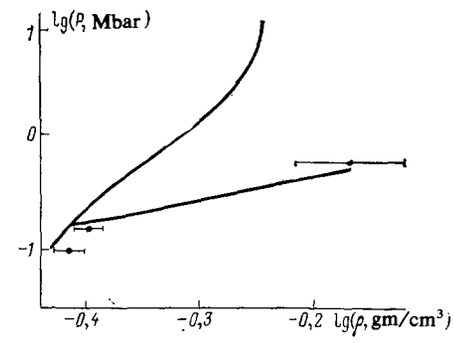

FIG. 3. The first and second shock adiabats of helium. The points with the confidence intervals are the measured values;[6] the solid line shows the calculation using TFC.[2]

in this region. We analyzed the experimental data[4] shown in Fig. 1 using a special technique which reveals the phase transition at $P = 70$ kbar on the cold-compression curve of hydrogen.

The reasonable agreement between the computed and experimental curves in Figs 1 and 2 (as well as Fig. 3, which shows the calculation of the first and second shock adiabats of He under conditions corresponding to the experimental conditions[6]) provides a basis for constructing wide-range equations of state of hydrogen, helium, and other noble gases.

These encouraging results suggest that the development of the microscopic approach to the study of compressibility on the basis of scattering data is promising. Important problems in this direction are the experimental study of the effects of nonadditivity of the interactions in the mega-gigabar pressure range and reconstruction from the scattering of molecular systems not only of the effective spherically symmetrical potentials, but also the complete potential-energy surface taking into account the anisotropy of the interaction and the dependence on the intra-atomic distances in molecules.

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S. I. Anisimov and Yu. V. Petrov. *Equation of state of molecular hydrogen in the megabar range, role of nonpair interactions.* The approximation of pair interatomic[1,2] or pair intermolecular interactions is often used to calculate the thermodynamic functions of molecular crystals, including the molecular-hydrogen crystal.[3,4] It is obvious that the pair-interaction approximation for molecules in a crystal is only the first term in the general cluster expansion of the energy of