

A Critical Fluid in the Earth's Gravity Field

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Abstract—This work proposes a mechanism for the physical processes underlying the wide practical application of the unique properties of a substance in a critical state—critical fluid (CF)—in contemporary technologies. According to the fluctuation theory of phase transitions (FTPT), this mechanism may be due to the fluctuation and structural characteristics of a critical fluid, which determine its equilibrium and kinetic properties. Among such characteristics are the system correlation radius R_s , the number of order parameter fluctuations $N_f \sim R_s^{-3}$ per mole of critical fluid, and the fluctuation component of the thermodynamic potential

$F_f^* = N_f k T_c / (P_c V_c) = C_0 R_s^{-3}$. These structural characteristics are studied with the use of experimental gravity effect data, such as the altitude and temperature dependencies of the scattered light intensity $I(z, t)$ in a heterogeneous substance (*n*-pentane) near the critical vaporization temperature. Using these results and the literature data on the formation of Al_2O_3 nanoparticles with the use of SC- H_2O , the propagation velocity of substance molecules $v_f \approx 10^6$ cm/s is estimated for the origination and decay of order parameter fluctuations. It has been concluded that just such high propagation velocities of substance molecules most likely cause the unique properties of a critical fluid during their practical application in a number of engineering processes.

Keywords: critical fluid, gravity field, fluctuation structure

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INTRODUCTION

The study of second-order phase transitions and critical phenomena in liquids still remains as one of the urgent problems of condensed matter physics [1–4]. An infinite increase in the system correlation radius R_s at the approach to a critical point leads to the appearance of unique (singular) phenomena in condensed systems, namely, an infinite increase in the compressibility, heat capacity, heat conductivity, viscosity, and the time to reach equilibrium of a system and also to a considerable decrease in the macrodiffusion, thermal diffusivity, surface tension, and other characteristics of substances in a critical state [5, 6].

These unique equilibrium and critical properties of a substance in a critical state find wide practical application in contemporary technologies [7–10].

Thus, for instance, supercritical extraction (SCE) with carbon dioxide SC- CO_2 enables the most complete and fast recovery of caffeine, essential oils, radioprotective and bioactive compounds, and many other substances from vegetable and animal products and increases the production of crude oil and its separation from heavy fractions and metals in petrochemical processes and many other fields.

The unique dissolving ability of SC- H_2O is efficiently applied for the purification of the environment from industrial organic and radioactive waste contam-

inants, for the elimination of chemical and bacteriological weapons, and the development of advanced technologies for the production of new biofuels, which is an urgent problem of contemporary power engineering. SC- H_2O is also intensively applied for the synthesis of nanoparticles with specified properties.

Special emphasis should be laid on the great role of SC- H_2O in the nature. The formation of the Earth's crust, volcanic activity, the transfer and concentration of ore-forming components in deposits, and many others—all these phenomena result from the activity of a supercritical hydrothermal fluid.

REGION OF CRITICAL FLUID PARAMETERS

At the present time, researchers of the critical state of a substance consider it as a special aggregative state [11, 12], namely, a supercritical fluid (SCF). However, it should be noted that the term “supercritical fluid” formally limits the P – ρ – T parameter region, in which the unique properties of this “aggregative” state of a substance are exhibited. Indeed, according to FTPT [1–4], this P – ρ – T parameter region of the “new aggregative” state of a substance belongs to the entire critical fluctuation region. As follows from the Ginzburg criterion $Gi \ll 1$ [1–3] and numerous experimental data [5, 6, 11], this critical fluctuation region is

characterized by the parameters $\Delta P^* = (P - P_c)/P_c = 0-10^{-1} \ll 1$, $\Delta \rho^* = (\rho - \rho_c)/\rho_c = 0-10^{-1} \ll 1$, and $t = (T - T_c)/T_c = 0-10^{-1} \ll 1$ and incorporates both supercritical ($T > T_c$) and subcritical ($T < T_c$) temperatures (P_c , ρ_c , and T_c are the critical pressure, density and temperature of a substance). It may be suggested that the unique properties of this “new aggregative” state of a substance will find their wide practical application in the nearest future not only in the supercritical region of temperatures (SCF, $T > T_c$), but also in the subcritical region ($T < T_c$). For this reason, the “new aggregative” state of a substance with its unique properties can be assigned to the entire critical fluctuation region of temperatures $T > T_c$ and $T < T_c$, which we propose to name “critical fluid.”

In the scientific literature [13, 14], the wide possibilities of the practical application of the unique properties of a supercritical fluid are argued by its relatively low viscosity and high diffusion coefficient in the supercritical temperature region. However, as follows from FTPT [1–4] and the dynamic theory of critical phenomena [15, 16], the viscosity of a critical fluid ($\nu = 0.63$ is the critical correlation radius parameter, $z = 0.06$ is the critical viscosity parameter) increases, and the diffusion coefficient $D \sim (R_s^{-1}) \sim t^\nu$ considerably decreases at the approach to the critical state of a substance. For this reason, comparing the mutually exclusive conclusions [13, 14] and [15, 16], it is possible to state that the true mechanism of physical processes in critical and supercritical fluids, which are rather widely used in various technologies, unfortunately, has not completely been clarified. However, the understanding of the processes occurring in critical media is very important for the comprehensive selection of engineering process parameters and the interpretation of global natural phenomena in the Earth's crust.

It should also be noted that the essential experimental and theoretical studies of the critical state of a substance (critical fluid) concern spatially homogeneous systems [5, 6], in which the phenomenon of the gravity effect is eliminated by stirring. However, truly equilibrium systems are spatially heterogeneous under the real conditions of a physical experiment in the Earth's gravity field [17–20]. Such spatial heterogeneity in an equilibrium state enables the measurements of both the temperature and field (altitude) dependencies of various properties of a substance in a critical state under natural conditions.

At the present time, the problem of studying the critical phenomena in spatially heterogeneous systems in the Earth's gravity field has gained special importance due to the intensive studies of the equilibrium and kinetic properties of critical fluids under spaceflight microgravitation [21–24]. A demonstrative example of the first similar studies is the program

“Universal Furnace” completed within the Apollo-Soyuz test project as early as in the 1970s [24].

In connection with the aforesaid, the further studies of the fundamental properties of critical fluids for the use of their unique properties under both Earth conditions and spaceflight microgravitation are currently topical.

FLUCTUATION STRUCTURE OF A CRITICAL FLUID

In view of the FTPT statement [1–4] about the fluctuation structure of a substance in a critical state and the fluctuation mechanism of the origination and decay of order parameter fluctuations, this paper pays special attention to the study of the structural characteristics of a real heterogeneous critical fluid in the Earth's gravity field.

According to FTPT [1–4], a critical fluid represents a fluctuationally dispersed system by its structure, i.e., a gas of order parameter fluctuations, whose size is characterized by the system correlation radius R_s . The fluctuation component of the thermodynamic potential of such a system near the critical point ($T \rightarrow T_c$, $P \rightarrow P_c$, $\rho \rightarrow \rho_c$) is determined by the relationship similar to the ideal gas energy equation [5, 25]

$$F_f^* = \frac{F_f}{P_c V_c} = \frac{N_f k T_c}{P_c V_c} = \frac{R T_c}{P_c V_c} \frac{N_f}{Z_c N_A} = C_0 R_s^{-3}. \quad (1)$$

In this formula, $N_f \sim R_s^{-3}$ stands for the number of order parameter fluctuations per system's mole instead of the number of substance molecules, N_A is the Avogadro number, R is the universal gas constant, k is the Boltzmann constant, $Z_c = P_c V_c / R T_c$ is the critical compressibility factor of a substance, and P_c , V_c , T_c , and ρ_c are the critical pressure, volume, temperature, and density of a substance, respectively. Reasoning from FTPT [1–4], the correlation radius is presented by the scaling relationships $R_s^{-1} = t^\nu \Phi_1(Z_1^*) = \Delta \mu^\xi \Phi_2(Z_2^*)$. Here, $\Phi_1(Z_1^*)$ and $\Phi_2(Z_2^*)$ are the scaling functions for the variables $Z_1^* = \Delta \mu t^{-\beta \delta}$, and $Z_2^* = (Z_1^*)^{-1/\beta \delta} = t(\Delta \mu)^{-1/\beta \delta}$, $\Delta \mu = (\mu - \mu_c)/(P_c \rho_c) = (P - P_c)/P_c = \Delta P$, $t = (T - T_c)/T_c$, μ_c is the critical chemical potential, and ν , ξ , β , and δ are the critical FTPT parameters [1–4].

Along limiting thermodynamic directions, i.e., a critical isochor ($Z_1^* \ll 1, t > 0$), a critical isotherm ($Z_2^* \ll 1$),

and a phase interface ($|Z_1^*| \ll 1, t < 0$), the correlation radius can respectively be written in the form [1–3]

$$R_s^{-1} = t^\nu \Phi_1(Z_1^*) = t^\nu \sum_{n=0}^{\infty} a_n (\Delta\mu t^{-\beta\delta})^{2n};$$

$$R_s^{-1} = \Delta\mu^\xi \Phi_2(Z_2^*) = \Delta\mu^\xi \sum_{n=0}^{\infty} d_n (t\Delta\mu^{-1/\beta\delta})^n; \quad (2)$$

$$R_s^{-1} = |t|^\nu \Phi_1(|Z_1^*|) = |t|^\nu \sum_{n=0}^{\infty} b_n (\Delta\mu t^{-\beta\delta})^n.$$

As follows from Eqs. (1) and (2), the field and temperature dependencies of the correlation radius of a critical fluid $R_s(\Delta\mu, t)$, which characterizes the linear dimensions of order parameter fluctuations, should be classified among the structural characteristics of a critical fluid.

This fluctuation structural characteristic of a critical fluid also determines its kinetic properties [5, 15, 16], such as the lifetime of order parameter fluctuations $t_s \sim R_s^3$, the diffusion coefficient $D \sim R_s^{-1}$, and the shear viscosity $\eta_s \sim R_s^{\eta}$.

The fluctuation component of the thermodynamic potential $F_f^* = (N_f k_B T_c)/(P_c V_c) = C_0 R_s^{-3}(\Delta(\mu, t))$ is a basis for finding the thermal and caloric equations of state for a critical fluid. Indeed, all the polynomial equations of state for a substance along the limiting critical directions, such as a critical isochor, a critical isotherm, and a phase interface [1] follow from the fundamental FTPT relationship (1) [1–3]:

$$\Delta\rho = dF_f/d\mu; \quad \Delta\rho(t) = B_0 |t|^\beta;$$

$$\Delta\rho(\Delta\mu) = D_0 |\Delta\mu|^{1/\delta};$$

$$(d\rho/d\mu)_T = d^2 F_f/d\mu^2 = \Gamma |t|^{-\gamma}; \quad (3)$$

$$\Delta s = dF_f/dt = S_0 |t|^{1-\alpha};$$

$$C_v = d^2 F_f/dt^2 = A |t|^{-\alpha}.$$

These thermal and caloric equations of state for a critical substance are valid in the parametric region of $\Delta P^* = (0-10^{-1}) < 1$, $\Delta\rho^* = (0-10^{-1}) < 1$, and $t = (0-10^{-1}) < 1$.

The study of these equations of state for a substance and its kinetic characteristics is one of the major problems of any physical study performed in the critical region.

STRUCTURAL CHARACTERISTICS OF A CRITICAL FLUID IN THE EARTH'S GRAVITY FIELD

The above-described forms of the fluctuation component of the thermodynamic potential F_f^* (Eq. (1))

and the equation of state for a substance (Eq. (3)) characterize spatially homogeneous systems. However, a critical fluid becomes spatially heterogeneous along the height in an equilibrium state under real conditions of a physical experiment at the approach to a critical point ($t \rightarrow 0, \Delta\rho \rightarrow 0$) due to an infinite increase in the compressibility of a substance in the Earth's gravity field [17–20]. The altitude and temperature dependencies of the scattered light intensity $I(z, T)$, the refractive index gradient $dn/dz(z, T)$, and the density of a substance $\rho(z, T)$ were studied using different experimental methods, i.e., molecular light scattering, refractometry, and slow neutron transmission. The experimental data on the gravity effect are related with the altitude distribution of different structural characteristics of a heterogeneous critical fluid, such as R_s, N_f , and F_f in an external gravity field $h = \rho_c g z/P_c$ (g is the acceleration due to gravity, z is the height measured from a critical substance density level), thus enabling the determination of the altitude and temperature dependencies of the correlation radius $R_s(z, t)$ of a heterogeneous critical fluid in the Earth's gravity field.

Thus, the correlation radius $R_s(z, t)$ of a substance can be calculated from the experimental data on the altitude and temperature dependencies of the scattered light intensity $I(z, t)$ by the known relationship [2, 20, 26, 27] as

$$R_c(z, t) = \frac{1}{q} \left[\left(\frac{I_c}{I(z, t)} \right)^{1+\frac{\eta}{2}} - 1 \right]^{-\frac{1}{2}}, \quad (4)$$

where I_c is the scattered light intensity at a critical point ($z = 0, t = 0$), $q = 4\pi/(\lambda \sin(\theta/2))$ is the transmitted wave vector, λ is the scattered light wavelength, $\eta = 0.06$ is the critical exponent of the correlation function, and $G(r) \sim 1/r^{1+\eta}$ [2].

The altitude and temperature dependencies calculated for the correlation radius of a heterogeneous substance (*n*-pentane) in the Earth's gravity field by Eq. (4) are plotted in Fig. 1 (see the color insert).

The dependencies of the correlation radius $R_s(h, t)$ along the thermodynamic directions, such as a critical isochor ($z = 0, t > 0$) (Fig. 1, curve 1), a phase interface ($z = 0, t < 0$) (2), and a critical isotherm ($t = 0$) (3) are described, respectively, by the relationships

$$R_c = r_1 t^{-\nu}; \quad R_c = r_2 |t < 0|^{-\nu};$$

$$R_c = r_3 |h|^{-\xi}, \quad (5)$$

where $\nu = 0.636$ and $\xi = 0.405$ are the critical parameters [1–3, 28], $r_1 \approx 3.8 \text{ \AA}$, $r_2 \approx 2 \text{ \AA}$, and $r_3 \approx 1 \text{ \AA}$ are the amplitudes [26, 27], and $h = \rho_c g z/P_c$ is the gravity field variable.

As follows from these data, the correlation radius varies within a range of $R_s = 1-100 \text{ nm}$ in the region of heights $z = 0-10 \text{ cm}$ and $|h| = 0-10^{-4}$ and tempera-

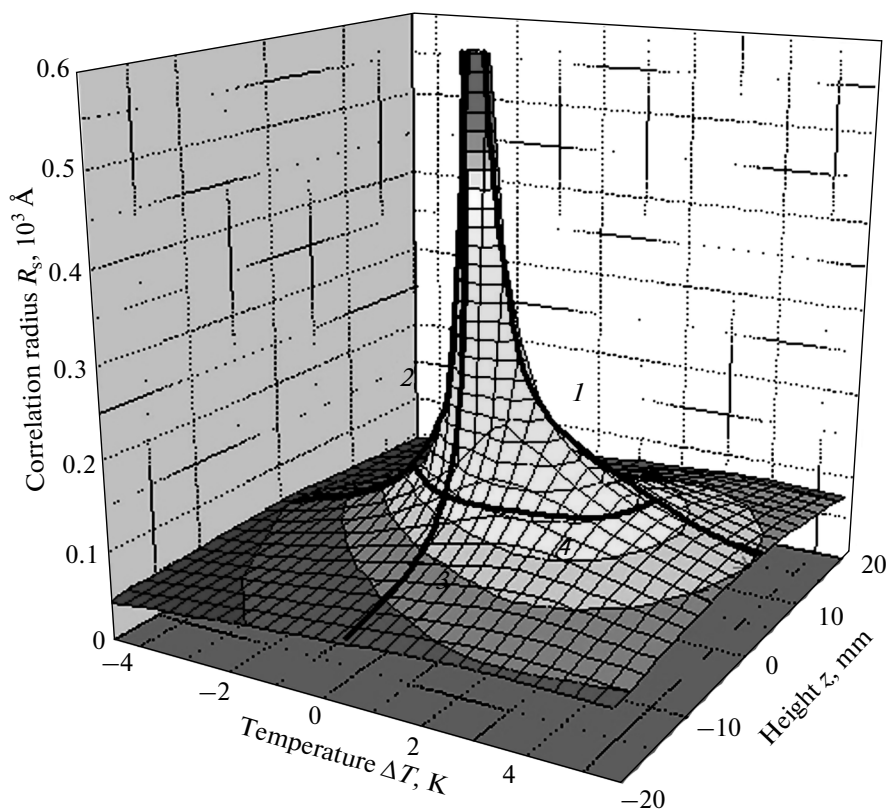


Fig. 1. Three-dimensional surface of the symmetrized correlation radius $R_s(h, t) = [R_s(h > 0, t) + R_s(h < 0, t)]/2$ of a heterogeneous substance (*n*-pentane) as a function of height z and temperature $\Delta T = T - T_c$.

tures $t = (10^{-2} - 10^{-4})$. This neighborhood of a critical point in Fig. 1 is outlined by curve 4.

Using these data on $R_s(h, t)$ (Fig. 1), it is possible to find the fluctuation component of the thermodynamic potential $F_f^*(t, h) = C_0 R_s^{-3}(t, h)$ [20, 29], but this requires C_0 to be determined.

In this work, C_0 is calculated using the equations of state for a critical fluid in the form related, according to FTPT, with the scaling functions of the correlation radius (Eq. (2)). As follows from these relationships, the equation of state along the thermodynamic direction of a critical isotherm ($t = 0$) has the following form:

$$\begin{aligned} \Delta\rho(\Delta\mu) &= dF_f/d\mu \\ &= 3\xi C_0 d_0^3 \Delta\mu^{3\xi-1} = D_0 \Delta\mu^{1/\delta}, \end{aligned} \quad (6)$$

where $D_0 = 3\xi C_0 d_0^3$; $3\xi - 1 = 1/\delta$; $\xi = 0.405$, $\delta = 4.64$, and $C_0 = D_0/(3\xi d_0^3)$.

From this expression, the parameter $C_0(D_0, d_0) \approx 1.3 \times 10^{-22} \text{ cm}^3$ was found for *n*-pentane. This was accomplished using the data of P - V - T measurements [5, 6] and the scattered light intensities [20], which enable the calculation of the two parameters $D_0 \approx 0.77$ and $d_0 \approx 1.7 \times 10^7 \text{ cm}^{-1}$. The value of C_0 was found

close to $C_0 \approx 10^{-22} \text{ cm}^3$, which was theoretically calculated by Yukhnovskii [30] for CO_2 by the method of collective variables.

The value obtained for C_0 allows us to plot the surface $F_f^*(t, h) = C_0 R_s^{-3}(t, h)$ [20, 29] (see Fig. 2 in the color insert).

Using the surface $F_f^*(t, h)$ (Fig. 2), it is possible to calculate various thermal and caloric properties of a heterogeneous critical fluid, such as the density $\Delta\rho = dF_f^*/d\mu$, the compressibility $\beta_T = d^2 F_f^*/d\mu^2$, the entropy $\Delta s = dF_f^*/dt$, and the heat capacity $C_v = d^2 F_f^*/dt^2$.

Using the surface F_f^* (Fig. 2), it is also possible to determine the number of "drops," i.e., clusters of order parameter fluctuations per mole of substance from Eq. (1) as $N_f = N_A Z_c C_0 R_s^{-3} = N_A Z_c F_f^*$. The results of such processing are shown in Fig. 3 (see the color insert).

This qualitative characteristic of a critical fluid [5, 25] (*n*-pentane) along the limiting thermodynamic directions of a critical isochor, a phase interface, and a

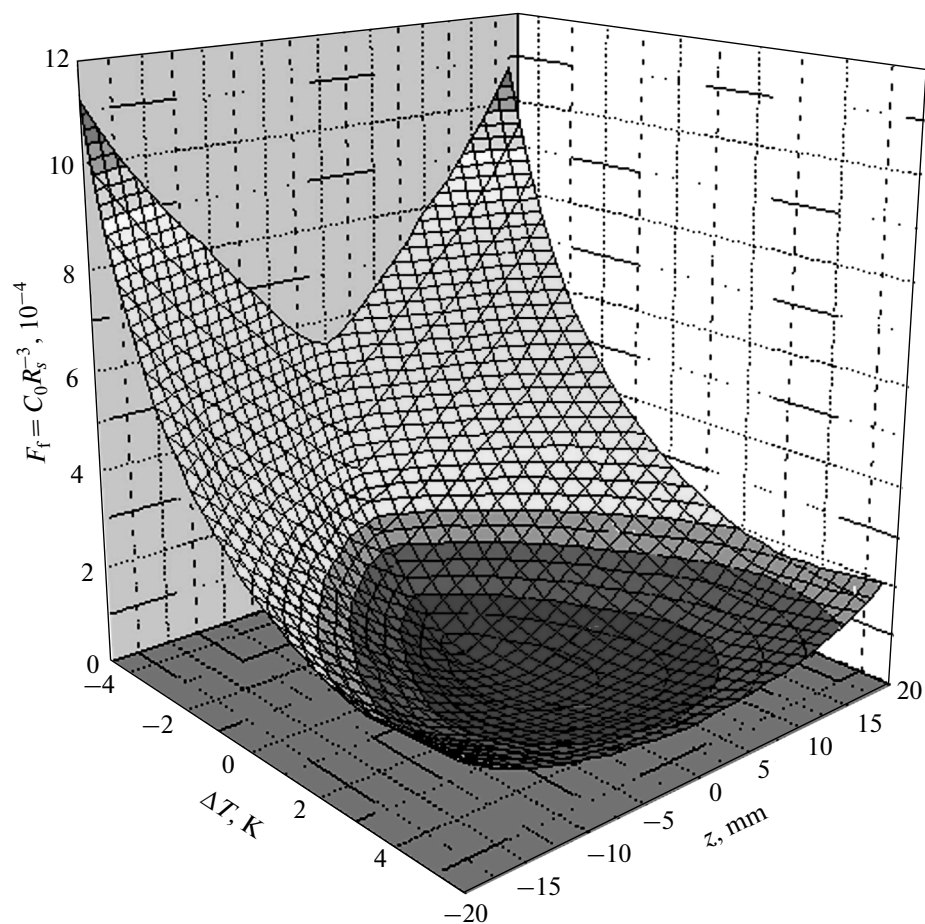


Fig. 2. Three-dimensional surface of the thermodynamic potential F_f^* in heterogeneous n -pentane in the Earth's gravity field as a function of height z and temperature $\Delta T = T - T_c$.

critical isotherm can be correspondingly written in the form [20]

$$\begin{aligned} N_f &= 2.9 \times 10^{23} t^{3v}; & N_f &= 2 \times 10^{24} |h|^{3v}; \\ N_f &= 2 \times 10^{25} |h|^{3\xi}. \end{aligned} \quad (7)$$

STRUCTURAL CHARACTERISTICS OF A CRITICAL FLUID ACCORDING TO NEUTRON AND OPTICAL SPECTROSCOPY

The further analysis of the structural characteristics of a critical fluid can be performed using the experimental data of optical and neutron spectroscopy from the works [31–35] and the results of theoretical calculations [10].

According to the data of double-differential cross sections for the noncoherent scattering of slow neutrons by water near a critical fluid, it has been concluded in the works [31, 32] that their structure can be described by the sum of two “gas-like” and “liquid-like” components. The double-differential cross sec-

tion of supercritical water consists of the double-differential cross sections for the scattering of water molecule monomers on an ideal gas ($\rho_g \ll \rho_c$) and the double-differential cross sections of scattering on liquid water, which is no different from subcritical water ($\rho_l = (2-3)\rho_c$).

These conclusions made on the basis of neutron spectroscopy [31, 32] are confirmed by the optical spectroscopy results [33–35] obtained for water by IR spectroscopy and Raman light scattering. These works point out that the supercritical water phase has both “gas-like” and “liquid-like” spectral characteristics, thus indicating the existence of local rarefactions and compressions in the supercritical fluid.

The results of experimental studies [31–35] are confirmed by the conclusions of the theoretical work [10], according to which “the critical state is a random state, in which half of the local volumes is strongly rarefied, and the other half is compressed by nearly two times with respect to the critical density (“fifty-fifty,” since local density fluctuations do not change the total number of fluid particles).”

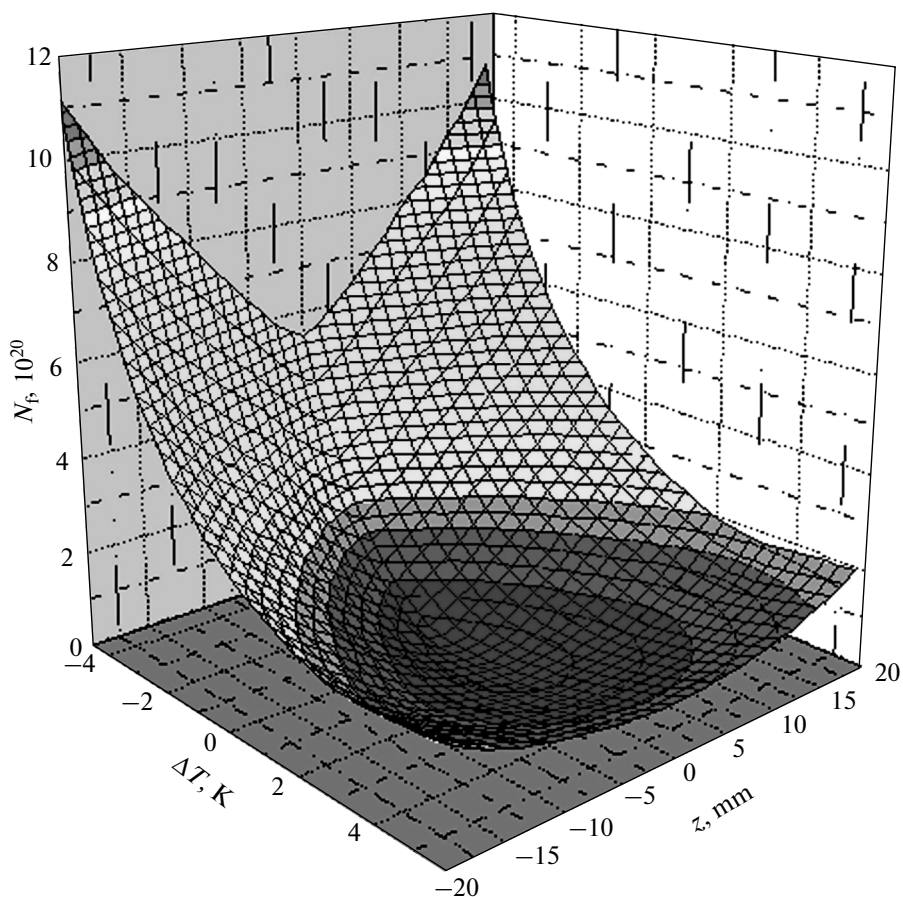


Fig. 3. Three-dimensional surface of the number of order parameter fluctuations N_f per n -pentane mole as a function of height z and temperature $\Delta T = T - T_c$.

The mentioned areas of local rarefaction and compressions of a substance near a critical fluid with $\rho_1 \approx (2-3)\rho_c$ agree with the notions about spatial scale invariance near a critical fluid [1], when the deviation of the local density in the correlated volume of a large-scale order parameter fluctuation is comparable with the average system density parameter itself [32].

From the obtained result $\rho_f \approx 3\rho_c$ it is possible to draw the conclusion that the substance density attains the liquid density $\rho_l \approx 3\rho_c$ far from the critical temperature at a critical substance temperature T_c inside fluctuation volumes $v_f = 4/3\pi R_s^3$, and the pressure in these fluctuation formations P_f may exceed the critical pressure $P_f > P_c$. In other words, the intermolecular interaction forces in these fluctuation formations also considerably increase.

According to the dynamic theory of critical phenomena [15, 16] and the existing experimental data [5], the lifetime $\tau_f \sim R_s^3$ of such local fluctuation formations in the critical region of temperatures $t < 10^{-2}$ attains $\tau_f \sim 10^{-6} - 10^{-8}$ s. An order parameter fluctuation decays in a certain lifetime τ_f . In this case, sub-

stance molecules fly away from each other at high velocities v_f , which considerably exceed their thermal velocity $v_f \gg v = (3RT_c/M)^{1/2}$, to group into a next order parameter fluctuation in some other place.

These velocities in CF-H₂O attain $v_f \gg 105$ cm/s. To estimate a certain value of such molecular velocities, let us engage the results from the work in [8], in which the formation of Al₂O₃ nanoparticles in CF-H₂O was studied. The performed calculation shows that such a process requires the kinetic energy of water molecules $W_f = m v_f^2 / 2$ in the decay of an order parameter fluctuation to be higher than the sublimation energy of one Al molecule. Since the molar Al sublimation energy $E_s = 301.7$ kJ/mol [8], the velocity of CF-H₂O molecules must be $v_f \approx 10^6$ cm/s. Then the kinetic energy of a CF-H₂O molecule must be $W_f \geq 10^{-11}$ erg, which is much higher than the thermal motion energy of molecules $W_T \approx 10^{-13}$ erg.

Relying on this model for the origination and decay of order parameter fluctuations in a critical fluid, it is possible to hypothesize that just high energies and velocities of substance molecules ($v_f \approx 10^6$ cm/s) are

likely to be the main reason for the appearance of the unique properties of a critical fluid in their practical application [7–10].

CONCLUSIONS

(1) In this work, different structural characteristics of a heterogeneous substance (*n*-pentane) have been studied near its critical vaporization temperature on the basis of experimental data obtained from the study of the gravity effect, namely, the altitude and temperature dependence of the scattered light intensity $I(z, t)$. We have studied the field and temperature dependencies of the correlation radius $R_s(h, t)$, the number of order parameter fluctuations $N_f(h, t)$ per mole of substance, and the fluctuation component of the thermodynamic potential $F_f^*(h, t) = N_f k T_c / (P_c V_c) = C_0 R_s^{-3}$.

(2) The field and temperature dependencies and the structural characteristics of a critical fluid $R_s(h, t)$, $N_f(h, t)$, and $F_f^*(h, t)$ provide a possibility to define the

equations of state for a substance $\Delta\rho = \frac{dF_f^*}{d\mu}$ and

$\frac{d\rho}{d\mu} = \frac{dF_f^{2*}}{d\mu^2}$ over the entire fluctuation region of a critical fluid in both the subcritical ($t < 0$) and supercritical ($t > 0$) temperature regions and to determine its kinetic characteristics, such as the viscosity $\eta \sim R_s^z$, the diffusion coefficient $D \sim R_s^{-1}$, and the lifetime of order parameter fluctuations $\tau_f \sim R_s^3$.

(3) The found structural characteristics of a critical fluid, namely, $R_s(h, t)$, $N_f(h, t)$, and $F_f^*(h, t)$ provide a possibility to estimate the substance density $\rho_f \approx 3\rho_l$ inside a fluctuation volume $v_f = 4/3\pi R_s^3$. The existence of such high densities in a critical substance state (critical fluid) is confirmed by experimental data of optical and neutron spectroscopy.

(4) From the obtained result $\rho_f \approx 3\rho_c$, it is possible to draw the conclusion that the pressure P inside fluctuation volumes $v_f = 4/3\pi R_s^3$ at a critical temperature T_c for the substance considerably exceeds the critical pressure ($P \gg P_c$). In other words, the intermolecular interaction forces in these fluctuation formations also considerably increase. In this connection, substance molecules fly away from each other at velocities which considerably exceed their thermal motion velocity upon the decay of order parameter fluctuations in a certain lifetime.

(5) These molecular velocities of the substance were estimated using the results of experimental studies on the formation of Al_2O_3 nanoparticles in $CF-H_2O$. The velocity of $CF-H_2O$ molecules ($v_f \approx 10^6$ cm/s) in the

origination and decay of order parameter fluctuations was determined from the molar Al sublimation energy ($E_s = 301.7$ kJ/mol). From this result it is possible to draw the conclusion that sufficiently high velocities of molecules are likely to be the main reason for the appearance of the unique properties of a critical fluid in their practical application.

(6) Relying on the presented experimental data on the structural characteristics of a critical substance state and the propagation velocity of critical fluid molecules after the decay of order parameter fluctuations ($v_f \approx 10^6$ cm/s), it is possible to conclude that the unique properties of the gas phase in a critical fluid and a subcritical temperature region ($t < 0$) will also find their successive practical application. In this case, the use of the gas phase of a critical fluid may be very efficient in connection with this state being characterized by a lower viscosity and a higher diffusion coefficient in comparison with the supercritical temperature region at $\rho = \rho_c$.

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