Singularity of the diameter of the coexistence curve of ethane

L. A. Bulavin and Yu. I. Shimanskiĭ
T. G. Shevchenko Kiev State University

(Submitted March 19, 1979)

Pis'ma Zh. Eksp. Teor. Fiz. **29**, No. 8, 482–485 (20 April 1979)

To determine the temperature dependence of the diameter of the coexistence curve of ethane, we obtained data on the location of the phase boundary at $10^{-3}<|\tau|<5\times 10^{-2}$, using the method of slow-neutron transmission. The obtained values $1-\alpha-\beta = 0.57\pm 0.04$ and $\beta = 0.337 + 0.006$ are in agreement with the gauge theory: $\rho_d \sim |\tau|^{0.91\pm 0.05}$.

PACS numbers: 64.30. + t

The modern theories of critical phenomena[1] predict a singular behavior of the diameter of the coexistence curve (DCC) of liquid and vapor $\rho_d \sim |\tau|^{1-\alpha}$, where $\rho_d = (\rho_m + \rho_g)/2$, ρl and ρ_g are the densities of the coexisting phases, $\tau = (T - T_c)/T_c$, and α is the critical index whose value $\alpha \approx 0.077$ was determined by the renormalization-group method.[1] The singular behavior of DCC was initially reported by Artyukhovskaya *et al.*[2] and later confirmed by Weigner *et al.*, Gopal *et al.*, and Ivanov *et al.*[3] To determine the singularity of DCC, we conducted an experiment to determined the location of the liquid-vapor boundary (meniscus) at different temperatures and average filling densities of the sample with ethane, which was proposed by Berestov *et al.*[4] For the temperature interval $10^{-3} < |\tau| < 5\times 10^{-2}$, in which the effect of the gravitational field on the density distribution of the coexisting phases along the height is

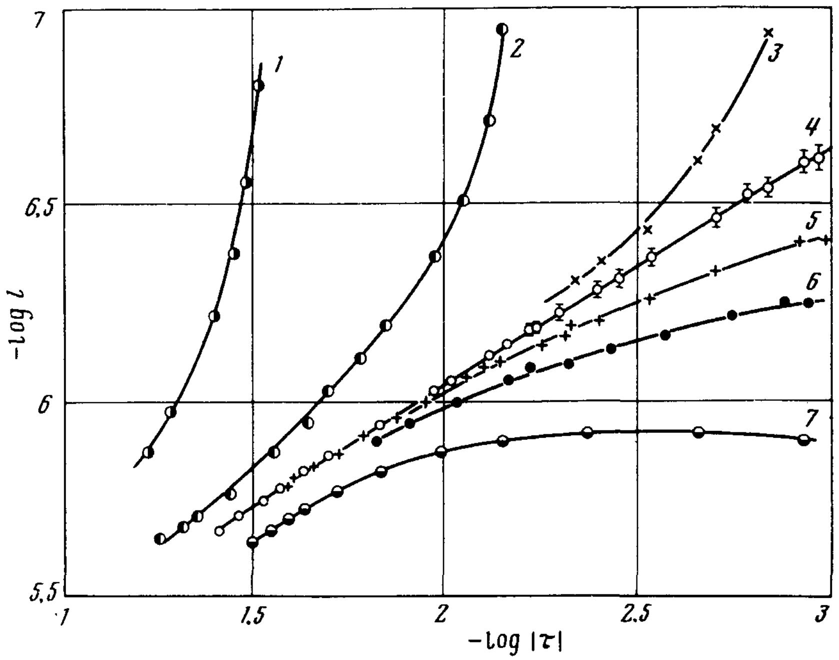

FIG. 1. Temperature dependence of the location of the meniscus in ethane for $\bar{\rho}$(g/cm^3): 1, 0.2103; 2, 0.2066; 3, 0.2062; 4, 0.2060; 5, 0.2058; 6, 0.2056; 7, 0.2052.

insignificant[5] and the contribution of the nonasymptotic terms to the equation for the coexistence curve is negligible,[6] the relative shift of the meniscus from the center of the sample, according to the expanded theory of gauge transformation,[1] has the form:

$$\frac{2l}{L} = \frac{B_1|\tau|^{1-\alpha} - D}{B_0|\tau|^{\beta}}, \tag{1}$$

where l is the shift of the meniscus from the center of the sample, β is the critical index of the coexistence curve, L is the height of the sample, and $D = (\bar{\rho} - \rho_c)/\rho_c$ is the relative deviation of the average density of the material in the sample from its critical value. At $\bar{\rho} = \rho_c$ it follows from Ref. 1 that $l \sim |\tau|^{1-\alpha-\beta}$, which enabled us to investigate DCC by the method of motion of the meniscus.

The location of the meniscus in ethane at different $\bar{\rho}$ and T was determined by the slow-neutron-transmission method.[7] The temperature controlled flat sample of constant cross section $S = 5$ cm^2 moved in a narrow neutron beam in vertical steps of 0.05 mm, which enabled us to determine the location of the phase boundary according to the neutron-transmission jump with an accuracy of 0.1 mm for $|\tau| > 10^{-3}$. The cascade thermostatic control circuit stabilized the temperature with an accuracy of 0.001 °C at temperature gradients along the sample's height ($L = 20$ cm) $\nabla T < 10^{-6}$ deg/cm. The $\bar{\rho}$ was varied by releasing the gas from the sample and measuring the gas volume at normal pressure, which made it possible to determine $\bar{\rho}$ with an accuracy of 0.02%.

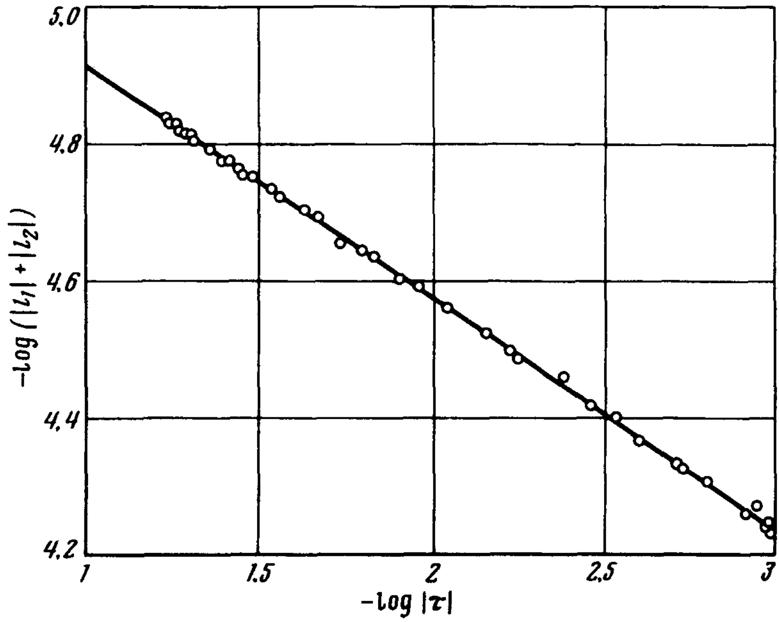

FIG. 2. Determination of the critical index of the coexistence curve for ethane by the method of shifting the meniscus.

The purity of ethane was 99.96%. The value of T_c (32.197 $\pm$ 0.005) °C was determined from the disappearance of the discontinuity in the neutron transmission as a result of moving the neutron beam from one phase to another. The data on the motion of the meniscus are shown on the logarithmic scale in Fig. 1. A number of experiments at different $\bar{\rho}$ made it possible, according to Ref. 1, to determine the value $\rho_c = (0.2058 \pm 0.0001)$g/cm^3 and for $\bar{\rho} = \rho_c$ to determine the exponent of the temperature dependence of the shift of the meniscus from the center of the sample: $1-\alpha-\beta = 0.57 \pm 0.04$, taking into account the measurement errors of τ and l. To determine the critical index β in the indicated temperature interval, we constructed a dependence

$$|l_1(\bar{\rho}_1, \tau)| + |l_2(\bar{\rho}_2, \tau)| = 2B_o^{-1} D|\tau|^{\beta}$$

for $\bar{\rho}_1 = 0.1782$ g/cm^3 and $\bar{\rho}_2 = 0.2335$ g/cm^3 ($\bar{\rho}_1 - \rho_c \approx \rho_c - \bar{\rho}_2$), which is shown on the logarithmic scale in Fig. 2. On the basis of the determined values $\beta = 0.337 \pm 0.006$ and $1-\alpha-\beta$, we can conclude that $1-\alpha = 0.91 \pm 0.05$ in the temperature interval $10^{-3} < |\tau| < 5 \times 10^{-2}$, which indicates that the diameter of the coexistence curve of ethane is singular.

[1]A.Z. Patashinskiĭ and V.L. Pokrovskiĭ, Fluktuatsionnaya teoriya fazovykh perekhodov (Fluctuation Theory of Phase Transitions), Nauka, M., 1975.

[2]L.M. Artyukhovskaya, E.T. Shimanskaya, and Yu. I. Shimanskiĭ, Zh. Eksp. Teor. Fiz. **63**, 2159 (1972) [Sov. Phys. JETP **36**, 1140 (1973)].
[3]J. Weiner, K.H. Langley, and N.G. Ford, Phys. Rev. Lett. **32**, 879 (1974); E.S.R. Gopal, R. Ramachandra, P. Chandra Seknar, K. Govindazajan, and S.V. Subramanyam, Phys. Rev. Lett. **32**, 284 (1974); D. Yu. Ivanov, L.A. Makarevich, and O.N. Sokolova, Pis'ma Zh. Eksp. Teor. Fiz. **20**, 272 (1974) [JETP Lett. **20**, 121 (1974)].
[4]A.T. Berestov, E.E. Gorodetskiĭ, and V.M. Zaprudskiĭ, Pis'ma Zh. Eksp. Teor. Fiz. **21**, 56 (1975) [JETP Lett. **21**, 26 (1975)].
[5]P.C. Hoenberg and M. Barmatz, Phys. Rev. **A6**, 289 (1972).
[6]B.S. Maccaby and J.A. White, Phys. Lett. **60**, 179 (1977).
[7]L.A. Bulavin, P.G. Ivanitskiĭ, Yu. B. Mel'nichenko, and Yu. I. Shimanskiĭ, Ukr. Fiz. Zh. **23**, 1125 (1978) [Ukr. Phys. J. **23** (1978)].