form of a corrugated cylinder that is open along the [0001] axis, and the results of the experiment duplicate the corrugations of the surface up to three cycles [2].

Thus, the observed oscillations constitute a size effect on the electrons of the open surface. The harmonic character of these oscillations offers evidence that these electrons are "ineffective."

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[1] V. F. Gantmakher and E. A. Kaner, JETP 45, 1430 (1963), Soviet Phys. JETP 18, 988 (1964).
[2] V. F. Gantmakher and E. A. Kaner, JETP 48, 1572 (1965), Soviet Phys. JETP 21, 1053 (1965).
[3] V. F. Gantmakher, JETP 44, 811 (1963), Soviet Phys. JETP 17, 549 (1963).
[4] Yu. V. Sharvin and V. F. Gantmakher, PTE No. 6, 165 (1963).
[5] N. E. Alekseevskii and Yu. P. Gaidukov, JETP 43, 2094 (1962), Soviet Phys. JETP 16, 1481 (1963).
[6] I. D. Gavenda and B. C. Deaton, Phys. Rev. Lett. 8, 208 (1962).

1) The authors are grateful to B. N. Aleksandrov for supplying the pure cadmium.

2) These results will be described in detail in an article devoted to an investigation of the Fermi surface of cadmium.

DENSITY CORRELATION NEAR THE CRITICAL POINT

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The purpose of the present note is to determine, within the framework of the phenomenological theory, the dependence on the distance $r = |\vec{r}_1 - \vec{r}_2|$ of the correlation function of the density ρ

$$Q(r) = \langle \rho(\vec{r}_1)\rho(\vec{r}_2)\rangle - \langle \rho\rangle^2 \tag{1}$$

near the critical point of a liquid-vapor system, using data from thermodynamic experiments. The assumptions under which the calculations are made are similar to those made in [1]. We put

$$\tau = \frac{T - T_c}{T_c}, \qquad \nu = \frac{\mu_c - \mu}{T}, \tag{2}$$

where T_c and μ_c are the critical values of the temperature T and of the critical potential μ. We consider two kinds of averages: ordinary K_n averaged over the ensemble with $\nu = 0$

$$K_n(\vec{r}_1, \vec{r}_2, \ldots, \vec{r}_n) = \langle \rho(\vec{r}_1)\rho(\vec{r}_2)\ldots\rho(\vec{r}_n)\rangle \tag{3}$$

and irreducible averages Q_n

$$K_1(\vec{r}) = Q_1(\vec{r}) = \bar{\rho}(\tau),$$
$$K_2(\vec{r}_1, \vec{r}_2) = Q_2(\vec{r}_1, \vec{r}_2) + Q_1(\vec{r}_1)Q_1(\vec{r}_2), \tag{4}$$
$$K_3(\vec{r}_1, \vec{r}_2, \vec{r}_3) = Q_3(\vec{r}_1, \vec{r}_2, \vec{r}_3) + Q_1(\vec{r}_1)Q_2(\vec{r}_1, \vec{r}_2, \vec{r}_3) + Q_1(\vec{r}_2)Q_2(\vec{r}_1, \vec{r}_3) + \ldots + Q_1(\vec{r}_1)Q_1(\vec{r}_2)Q_1(\vec{r}_3).$$

The thermodynamic potential $\Omega(\tau, \nu)$ is represented by the expansion

$$\Omega(\tau, \nu) = \Omega(\tau, 0) - T\sum_{n=1}^{\infty}\frac{\Gamma_n(\tau)\nu^n}{n!}, \tag{5}$$

where

$$\Gamma_n = \int d^3_{r_1} \ldots d^3_{r_n}\, Q_n(\vec{r}_1, \ldots, \vec{r}_n). \tag{6}$$

If for $1 \ll r \lesssim r_c(\tau)$ we have

$$Q_2(\vec{r}_1, \vec{r}_2) = Q(r) \sim \frac{\text{const}}{r^{2\beta}}; \quad r = |\vec{r}_1 - \vec{r}_2| \tag{7}$$

(we take the intermolecular-force radius to be the unit of length, and $r_c(\tau)$ is the correlation radius), then in a region of size r_c the average number of particles N receives a correlation increment ΔN of the order of

$$(\Delta N)^2 \sim r_c^{6-2\beta}. \tag{8}$$

It is assumed that the main contribution to Γ_{2n} is made by the integration region $|\vec{r}_i - \vec{r}_j| \leq r_c(\tau)$, where $Q_{2n} \sim K_{2n}$, so that (see [1])

$$\Gamma_{2n} \sim Vr_c^{-3+2n(3-\beta)}. \tag{9}$$

For Γ_{2n+1} cancellation of contributions from different regions is possible. We shall not use the fact that the expansion for Ω is even. We assume that when $\tau \ll 1$, $\nu \ll 1$, and $r_c(\tau) \gg 1$ the main contribution to (5) is made by the terms that are principal in $r_c(\tau)$. Then

$$\Omega(\tau, \nu) = \Omega(\tau, d + VT\nu\bar{\rho}(\tau) + VTr_c^{-3}f(\nu r_c^{3-\beta}), \tag{10}$$

where $f(\sigma)$ is a dimensionless function. As $\tau \to 0$ we get $r_c(\tau) \to \infty$, and if we assume that $r_c(\tau)$ is of the order of the size of the region in which the temperature fluctuation $\Delta\tau \sim 1/r^{3/2}$ is comparable with τ, we obtain [2]

$$r_c(\tau) \sim \tau^{-2/3}. \tag{11}$$

Such an estimate is valid for the Ising model and does not contradict the experimental data. $\Omega(\tau, \nu)$ is not singular when $\tau \to 0$ and $\nu \neq 0$. From this we obtain in analogy with [1]

$$\Omega_{sing}(\tau, 0) \sim A\tau^2 \ln \tau; \qquad \rho(\tau, 0) - \rho_c \sim B\tau^{-2\beta/3}. \tag{12}$$

We include in the last term of (10) the contribution $\nu B\tau^{-2\beta/3}$ (which changes the function f) and obtain ultimately

$$\Omega(\tau, \nu) = \Omega(\tau, 0) + VT\nu\rho_c + VT\tau^2 f(\nu/\tau^{2 - 2\beta/3}). \tag{13}$$

From (13) we get

$$\rho(\tau, \nu) - \rho_c = \tau^{2\beta/3} f'(\nu/\tau^{2 - 2\beta/3}) \tag{14}$$

and ν is expressed in terns of the reduced volume $v = (V - V_c)/V_c$ and τ in the form

$$\nu = \tau^{2 - 2\beta/3} g(v/\tau^{2\beta/3}). \tag{15}$$

From (13) we obtain for the thermodynamic quantities

$$K_T = 1/V(\partial V/\partial p)_T \sim \tau^{4\beta/3 - 2} f''(\nu/\tau^{2 - 2\beta/3}), \tag{16}$$

$$C_v \sim A \ln \tau \tag{17}$$

(such a behavior of C_v is the consequence of the relation $r_c \sim \tau^{-2/3}$). Formula (13) should define the line of the equilibrium liquid-gas transition, so that some value of $\nu(\tau)$ should correspond to two different values of the density. The question of the concrete mechanism of this phenomenon would call for additional hypotheses concerning the analytic properties of $f(\sigma)$ (see [1] for the case of a lattice gas).

At any rate it follows from (13) that the line of the equilibrium transition corresponds to a certain value of the argument $\sigma_0 = \nu(\tau)/\tau^{2-2\beta/3}$ of the function $f(\sigma)$, so that the equation of the transition line is expressed in terns of the variables ν and τ by

$$\nu = \sigma_0 \tau^{2-2\beta/3}. \tag{18}$$

and in terms of the variables v and τ by

$$v = y_0 \tau^{2\beta/3}, \tag{19}$$

where $g(y_0) = \sigma_0$ (see (15)).

Comparison of (19) and (17) with the experimental data of [3-6] favors the value $\beta = 4/3$, so that

$$\langle \rho(r_1)\rho(r_2) \rangle - \langle \rho \rangle^2 \sim \frac{\text{const}}{|\vec{r}_1 - \vec{r}_2|^{3/2}}. \tag{20}$$

In this case formula (13) leads to thermodynamic consequences that agree qualitatively with th the results of [3].

A check on the correctness of formula (20) by more direct means (for example by scattering experiments) would be very useful. A criterion for the region of sufficient closeness to the critical point with respect to v and τ can be in this case good satisfaction of the relations $K_T \sim 1/\tau$ for the compressibility and $\tau \sim \text{const} \cdot v^2$ for the equilibrium transition curve.

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[1] A. Z. Patashinskii and V. L. Pokrovskii, JETP 50, 439 (1966), Soviet Phys. JETP 23, in press.

[2] G. V. Ryazanov, JETP 49, 1134 (1965), Soviet Phys. JETP 22, in press.

[3] M. Ya. Azbel', A. V. Voronel', and M. Sh. Gitterman, JETP 46, 673 (1964), Soviet Phys.

JETP 19, 457 (1965).
[4] M. I. Bagatskii, A. V. Voronel', and V. G. Gusak, JETP 43, 728 (1962), Soviet Phys. JETP 16, 517 (1963); A. V. Voronel', Yu. R. Chashkin, V. A. Popov, and V. G. Simkin, JETP 45, 828 (1963), Soviet Phys. JETP 18, 568 (1964).
[5] P. H. Sherman, Phys. Rev. Lett. 15, 141 (1965).
[6] M. H. Edwards, Phys. Rev. Lett. 15, 348 (1965).

MOSSBAUER EFFECT IN THE FERROELECTRIC $Pb(Fe_{1/2}Nb_{1/2})O_3$

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It was found in [1,2] that the probability of the Mossbauer effect on Sn^{119} impurity nuclei in the systems $Ba(Ti_{0.8}Sn_{0.2})O_3$ and $Ba(Ti_{0.99}Sn_{0.01})O_3$ has a minimum near the temperature T_c of the ferroelectric phase transition. A similar effect was observed in [3] for Co^{57} impurity nuclei in $BaTiO_3$. In the same investigation, singularities in the behavior of the quadrupole splitting and of the position of the symmetry center of the Mossbauer spectrum were also observed at T_c.

We have investigated the variation of the parameters of the Mossbauer absorption spectrum of Fe^{57} nuclei in the ferroelectric $Pb(Fe_{1/2}Nb_{1/2})O_3$ at the ferroelectric phase transition (T_c = 114°C) [4]. In our case the Mossbauer nucleus Fe^{57} was a component part of the ferroelectric lattice, unlike the previously investigated impurity nuclei Sn^{119} and Fe^{57} in $BaTiO_3$.

Samples of $Pb(Fe_{1/2}Nb_{1/2})O_3$ absorbers were made by the usual ceramic technology using $Fe_2^{57}O_3$ (60% Fe^{57}). An x-ray analysis has shown that the samples were single-phase and had a well pronounced structure of the perovskite type. The source was Co^{57} in stainless steel. The Mossbauer spectra were measured with apparatus operating at constant speed with a permanent-magnet vibrator [5,6]. The source was mounted on the vibrator and was at room temperature, while the stationary absorber was in an oven. The absorber temperature fluctuation did not exceed 1°.

Figure 1 shows a typical absorption spectrum of $Pb(Fe_{1/2}Nb_{1/2})O_3$ (absorber thickness 5 mg/cm^2; T = 20°C). The isomer shift for this spectrum is 0.52 ± 0.02 mm/sec, corresponding to trivalent iron, and the quadrupole splitting is equal to 0.37 ± 0.02 mm/sec. Figure 2a shows the temperature dependences of the area of the spectrum S(T) (normalized to the area of spectrum at T = 20°C), while Fig. 2b shows the quadrupole splitting $\Delta E_{qu}(T)$ and Fig. 2c shows the position of the symmetry of the spectrum $\delta(T)$. The $\Delta E_{qu}(T)$ and $\delta(T)$ curves were obtained with a 5 mg/cm^2 absorber. The S(T) curve was obtained with a 1 mg/cm^2 $Pb(Fe_{1/2}Nb_{1/2})O_3$ absorber (~0.05 mg/cm^2 Fe^{57}), which can be regarded as thin ($\sigma f' \sim 0.3$ if we assume by way of an estimate that $f' \sim 0.5$ at T = 20°C). The values of ΔE_{qu} and δ were determined by process-