In conclusion we note that our results, as well as those obtained with ionic crystals [11], allow us to introduce a correction for the reflection from the front in temperature measurements (see [14]). This correction is small for almost all investigated substances, and plays a significant role only for CCl_4 at pressures P > 200 kbar.

[1] I. L. Fabelinskii, Molekulyarnoe rasseyanie sveta (Molecular Scattering of Light), 1965.
[2] C. V. Raman and K. S. Venkataraman, Proc. Roy. Soc. 171A, 137 (1939).
[3] I. S. Rosen, JOSA 37, 932 (1947).
[4] R. M. Waxler and C. E. Weir, J. Res. NBS 67A, 163 (1963).
[5] R. M. Waxler, C. E. Weir, and H. M. Schamp, Jr., ibid. 68A, 489 (1964).
[6] K. S. Krishnan and S. K. Roy, Phil. Mag. 43, 1000 (1952).
[7] B. Oksengorn, Comptes Rendus 242, 2324 (1956).
[8] Ya. B. Zel'dovich, S. B. Kormer, M. V. Sinitsyn, and K. B. Yushko, Dokl. Akad. nauk SSSR 138, 1333 (1961) [Sov. Phys.-Dokl. 6, 494 (1961)].
[9] T. J. Ahrens and M. H. Ruderman, J. Appl. Phys. 37, 4758 (1966).
[10] A. V. Sokolov, Opticheskie svoistva metallov (Optical Properties of Metals), 1961.
[11] S. B. Kormer, K. B. Yushko, and G. V. Krishkevich, ZhETF Pis. Red. 3, 61 (1966) [JETP Lett. 3, 37 (1966)].
[12] I. M. Walsh and M. H. Rice, J. Chem. Phys. 26, 815 (1957).
[13] S. B. Kormer, M. V. Sinitsyn, G. A. Kirillov, and L. T. Popova, Zh. Eksp. Teor. Fiz. 49, 135 (1965) [Sov. Phys.-JETP 22, 97 (1966)].
[14] S. B. Kormer, M. V. Sinitsyn, G. A. Kirillov, and V. D. Urlin, ibid. 48, 1033 (1965) [21, 689 (1965)].

*
All liquids compressed in a shock wave lose their transparency as the intensity is increased (CCl_4, $P \geq 60 - 80$ kbar [12]; H_2O, $P \geq 300$ kbar). The mechanism of transparency loss is apparently connected with absorption of light by free electrons, just as in ionic crystals [13].

SPECIFIC HEAT OF ANHYDROUS NICKEL CHLORIDE AT LOW TEMPERATURES

M. O. Kostryukova and O. A. Zarubina
Physics Department, Moscow State University

Anhydrous nickel chloride $NiCl_2$ experiences a transformation into the antiferromagnetic state at a temperature $T_c \sim 52°K$ and belongs to the class of layered antiferromagnets, which were first considered by Landau [1]. In these antiferromagnets the spins are ferromagnetically arranged in the layers, and a relatively weak antiferromagnetic interaction takes place between the layers.

Crystallographically, the layered structure of $NiCl_2$ is of the D_{3d}^5 type, and the symmetry axis C_3 is directed perpendicular to the layers of the Ni ions. $NiCl_2$ is fully isotropic [2], both above and below T_c, and we can assume in this connection that in the antiferromagnetic state the spins are oriented in the basal plane.

Electron resonance was observed in single-crystal $NiCl_2$ at 9.2 GHz below T_c, down to 10°K, and is attributed to the presence of a low-frequency antiferromagnetic-resonance branch [3].

The specific heat of $NiCl_2$ was measured earlier above 14°K [4,5]. Measurements of the specific heat of $NiCl_2$ between 1.8 and 16°K were undertaken in the present work to ascertain the singularities of the energy spectrum of layered antiferromagnets.

The anhydrous nickel chloride was obtained from the hydrate $NiCl_2 \cdot 6H_2O$. The dehydration was in a stream of dry HCl at 400°C, after which the oven temperature was raised to 1000°C and the $NiCl_2$ was sublimated twice in the HCl stream. The anhydrous salt, weighing ~80 g, was placed in a calorimeter whose construction was described earlier [6].

The results of our measurements of the specific heat of $NiCl_2$ in the region from 1.8 to 16°K are shown in Fig. 1 in C and T coordinates. The same figure shows the data from [5], where the specific heat of $NiCl_2$ was investigated above 14°K (circles). We see that our measurements agree well with the latter. The experimental points obtained by us fall on a smooth curve.
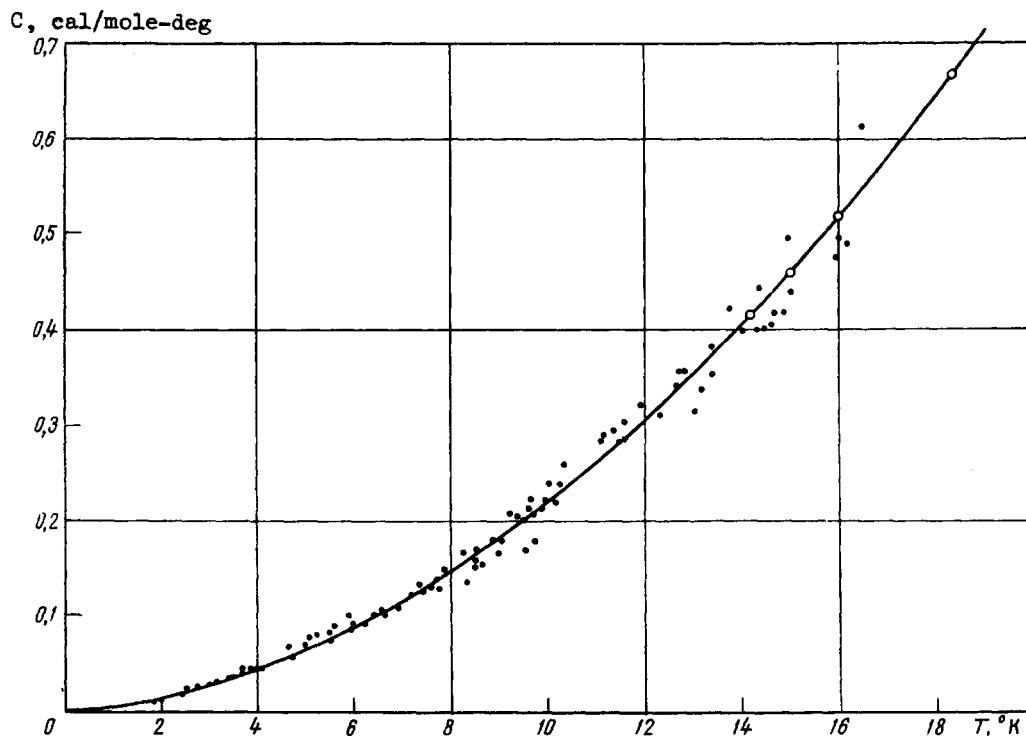

Fig. 1

Figure 2 shows the specific heat of $NiCl_2$ in the interval from 1.8 to 7°K in C and T^2 coordinates. We see that up to ~5°K the specific heat of $NiCl_2$ obeys the quadratic law

$$C \left[\frac{cal}{mole\text{-}deg}\right] = 2.93 \times 10^{-3} T^2.$$

Itskevich and Strelkov [7] investigated in detail the lattice specific heat of layered nonmagnetic halides of cadmium. For the isomorphic CdC_2 they obtained a cubic temperature dependence of the specific heat below 4.5°K, and the deviations from the Debye curve, which are inherent in layered lattices, were observed at higher temperatures. The specific heat of $CdCl_2$ at low temperatures is shown by the dashed curve of Fig. 2. A T^3 law for the lat-

tice specific heat was also observed below 4°K for the isomorphic $FeCl_2$ [8].
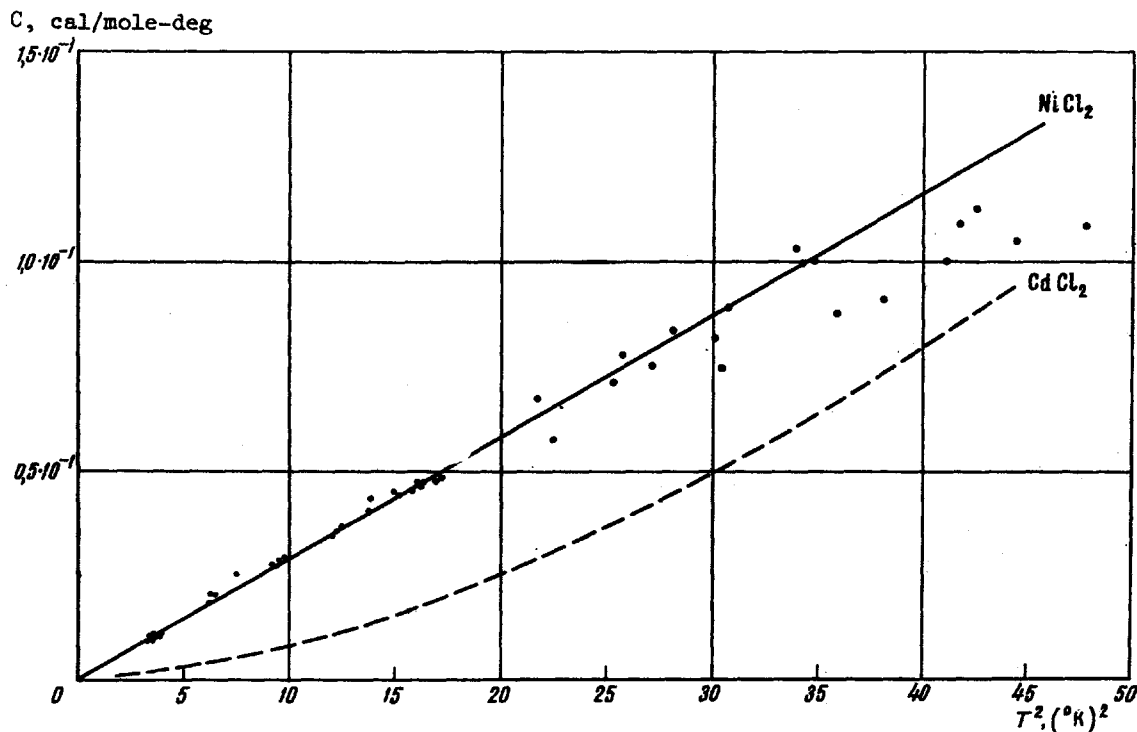
C, cal/mole-deg

Fig. 2

The total specific heat of $NiCl_2$ varies like T^2 at helium temperature, and its absolute magnitude greatly exceeds (by 2 - 6 times) the lattice specific heat of the isomorphic chlorides $CdCl_2$ and $FeCl_2$. At higher temperatures, however, the temperature plot of the specific heat of nickel chloride lies much lower than that of $CdCl_2$ or $FeCl_2$. Since there are no grounds for expecting an anomaly in the behavior of the lattice specific heat at low temperatures, where the T^3 law usually holds, it can be assumed that the contribution of the lattice to the total specific heat of $NiCl_2$ does not exceed the specific heat of $CdCl_2$ below 4°K.

The large specific heat of $NiCl_2$ in the helium region can be attributed in this case to the magnetic contribution, and the quadratic temperature dependence of the specific heat is apparently connected with the singularities of the magnetic energy spectrum of layered antiferromagnets.

The theoretical spin-wave spectrum in $NiCl_2$ was considered by Yoshimori [9], who showed that the low-frequency spin waves are analogous to the waves in a three-dimensional antiferromagnet and take the form of T^3 for the specific heat at low temperatures. The high-frequency waves, when the interaction between layers can be neglected, correspond to the case of a two-dimensional ferromagnetic system. The magnetic specific heat then varies linearly with the temperature. According to Yoshimori's estimates, the T^3 law should hold for the specific heat of $NiCl_2$ when $T \ll 4°K$, and the linear law should hold when $T \gg 10°K$. Our measurements were made, in accord with these estimates, in the intermediate temperature region.

In conclusion, we are deeply grateful to A. S. Borovik-Romanov, who took part in a discussion of the results, and to A. I. Shal'nikov for continuing interest in the work.

[1]   L. D. Landau, Sow. Phys. 4, 675 (1933).
[2]   H. Bizette, T. Terrier, and B. Tsai, Compt. rend. 243, 1295 (1956).
[3]   M. O. Kostoryukova and I. L. Skvortsova, Zh. Eksp. Teor. Fiz. 47, 2069 (1964) [Sov. Phys.-JETP 20, 1390 (1965)].
[4]   O. N. Trapeznikova, L. Shubnikov, and G. Milyutin, Sow. Phys. 9, 237 (1936).
[5]   R. H. Busey and W. F. Giauque, J. Am. Chem. Soc. 74, 4443 (1952).
[6]   M. O. Kostryukova, Dokl. Akad. nauk SSSR 96, 959 (1954).
[7]   E. S. Itskevich and P. G. Strelkov, Zh. Eksp. Teor. Fiz. 32, 467 (1957) [Sov. Phys.-JETP 5, 394 (1957)].
[8]   M. O. Kostryukova, ibid. 46, 1601 (1964) [19, 1084 (1964)].
[9]   A. Yoshimori, Phys. Rev. 130, 1312 (1963).

FERMI RESONANCE IN THE SRS SPECTRUM OF CRYSTALLINE n-NITROANILINE

Ya. S. Bobovich and A. V. Bortkevich
S. I. Vavilov Optics Institute

According to the quantum-mechanical theory of stimulated Raman scattering (SRS) developed by Javan in [1], a Stark shift of the line towards the violet side of the spectrum should be observed in a powerful light-wave field. In the typical case, sufficiently far from resonance, the magnitude of this shift is estimated in [1] to be on the order of 1 cm^{-1}. This effect is therefore difficult to observe in the condensed phase of matter, but it has been reliably established and is presistently investigated in gases [2]. Indirect information on the Stark level shift can be obtained in any phase of matter by investigating the Fermi resonance that accompanies this shift in certain spectra.

Fermi resonance is observed in the form of splitting of spectral lines whenever the frequency difference between oscillations of equal symmetry is of the same order of magnitude as their mechanical anharmonicity. The sharpness of the Fermi resonance is subject to the influence of intermolecular fields, or in general other external fields [3]; the character of this influence can be assessed from the position and relative intensity of the splitting components. We used this very property in the present investigation.

The object of the investigation was powdered n-nitroaniline, for which Fermi resonance is possible between the fundamental oscillations in the $C-NO_2$ and $C-NH_2$ groups [4,5]. Under certain conditions, the spontaneous Raman spectra of this substance actually revealed line splitting in the ~1330 cm^{-1} region, but its unique interpretation was made complicated by formation of a hydrogen bond [6]. The SRS generation in powders, which made it possible to perform the present investigation, was discovered by Sushchinskii and his co-workers [7]. The SRS spectra of n-nitroaniline were excited by us with a Q-switched ruby laser and were observed in reflected light. The maximum power in the ruby line was 20 MW/cm^2. The beam was focused on the material with a long-focus lens. A spectrograph with diffraction grating and 6 Å/mm dispersion was used.

At room temperature, the n-nitroaniline spectrum reveals, even at the maximum excita-