

Anomalous Heat Effects and Cold Fusion in KD_2PO_4 Crystals on the Ferroelectric Phase Transition

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1. Abstract

The kinetic peculiar features of the phase transition heat (ΔH) have been investigated by the differential scanning calorimetry method in KH_2PO_4 and KD_2PO_4 crystal on transition through the Curie point at preset rates of cooling and heating samples. It has been shown that on reaching a large number of thermal cycles the ΔH values of a KD_2PO_4 crystal are undergo inversion, so that the value of ΔH_{exo} begins to exceed that of ΔH_{endo} . Such an anomaly of the ΔH behavior is absent in the hydrogen-containing analogue of KD_2PO_4 , a KH_2PO_4 crystal, for which $\Delta H_{exo} > \Delta H_{endo}$ for any number of thermal cycles. A phenomenological model of an anomalous thermal effect in KD_2PO_4 crystals on a ferroelectric phase transition has been suggested, the transition being effected under explicitly nonequilibrium conditions. Using that model as a basis, the contribution of the domain walls elastic energy to the total transition heat has been calculated, the contribution being due to exoenergetic nuclear reactions taking place in the KD_2PO_4 crystal lattice on the splitting up of deuterons interacting with giant fluctuations of the domain walls elastic energy density

1. Introduction

The heat of a ferroelectric phase transition in the KDP and DKDP crystals, determinable through a corresponding integration of the temperature dependences of heat capacities under a constant pressure, was measured in works [1,2]. It is worthwhile to emphasize that the heat capacity values (i.e. transition heats) in the KDP and DKDP crystals were measured in the above-cited works under explicitly equilibrium conditions. Therefore, the total transition heat ΔH , associated only with the rebuilding of the crystalline structure on a phase transition, proves to be the same with regard to modulus, both on the heating and the cooling of samples. Now, it is to be expected that when measuring the transition heat under definitely (a fortiori) nonequilibrium conditions

(on the linear regime of cooling and heating of samples at different rates) the values of ΔH in the exophase (cooling) and the endophase (heating) may substantially differ in magnitude and exhibit a distinctly pronounced dependence on the heating rate. In such a case, because of the presence of a temperature gradient in a sample, some portion of the surface energy of domain walls, whose value attains $W'=40 \text{ erg/cm}^2$ [2], can transform into heat, thus giving rise to the anomalies of the phase transition heat during the thermocyclation of samples through the Curie point. In other words, this process must be equivalent to the appearance of an additional heat source ("cooler") in the crystal lattice, making a positive or negative contribution to the true transition heat.

In view of the aforesaid, the purpose of the present work consists in the investigation of a possibility of an additional yield of heat on a ferroelectric phase transition in the KDP and DKDP crystals, and of quantitative changes in the transition heat in the process of multiple thermocyclation (cooling and heating) of samples in the vicinity of T_C by the differential scanning calorimetry method (DSCM).

2. Methods

The ferroelectric phase transition heat was measured by the DSCM using a METTLER TA 3000 SYSTEM microcalorimeter allowing for cooling and heating samples according to the linear mode at a preset rate ($v_1=4.8 \text{ K/min}$ and $v_2=0.5 \text{ K/min}$) within a temperature range of 100–250 K, as well as for the integration of peaks, determination of the basis line and the temperature positions of peaks in an automatic regime. The KDP single crystals having the weight $m_H=6.5 \cdot 10^{-2} \text{ g}$ and the DKDP single crystals₂ (containing 97.0% deuterium) with the weight $m_D=5 \cdot 10^{-2} \text{ g}$ were used as sample; the DKDP samples containing₂ about 70% deuterium and having the weight $m_{HD}=5.0 \cdot 10^{-2} \text{ g}$ were utilized for control.

3. Results

The experimental values of the thermal effect parameters in the KDP and DKDP crystals are presented in the Table. In the KDP crystals with any number of thermal cycles ($n=1-82$) the transition heat in exoeffect (ΔH_{exo}) substantially (more than twofold) exceeds its value in the endoeffect (ΔH_{endo}).

An increase in the number of thermal cycles up to $n=80$ leads only to an insignificant (about 5%) narrowing of thermal peaks and to some decrease in the value of

ΔH_{exo} (Fig.1). During thermocyclation microcracks develop in crystals, which eventually leads even to a failure of the samples (the process of generation of defects).

In the DKDP crystals containing about 97% deuterium, the endoeffect magnitude exceeds that of the exoeffect until a certain amount of defects has been stored up in a sample—that is, during 10 to 20 initial thermal cycles (see Table, Fig.2, curve 1). Moreover, in distinction from the KDP crystals, with a large number of thermal cycles for a DKDP sample, the inversion of the absolute value of the thermal effect does occur in it, so that the transition heat in the exoeffect begins to exceed its value in the endoeffect (see Fig.2, curve 2). The DKDP crystals containing about 70% deuterium demonstrate the behavior of the transition heat, which is in many respects similar to that of the DKDP crystal with a maximum deuteration degree (see the Table; Fig.2, curves 3); yet, owing to the isotopic substitution effect, they exhibit different temperature positions of thermal peaks and somewhat lower (by about 10–20%) transition heats.

Let us note that during the thermocyclation of the KDP and DKDP (containing 97%) deuterium samples under the conditions near to the equilibrium ones — that is, at cooling and heating rates of the samples, which are lower by one order of magnitude ($v_2=0.5$ K/min), — there occurs a substantial decrease in the transition heat values, both in the exoeffect and in the endoeffect (Fig.3). These approach to their equilibrium values [1,2]. The temperature positions of the thermal peaks of the exoeffects and endoeffects simultaneously approach to each other, and their half widths drastically narrow. It is essential that no inversion of the absolute value of the peaks does occur in relation to the thermal peaks obtained at high heating-cooling rates.

Thus, the experimental data show that ferroelectrics with the KDP structure, whether containing deuterium or not, demonstrate completely different behaviors of the phase transition heat on the thermocyclation in the vicinity of the T_C .

In our experiments with a large number of thermal cycles we have observed a noticeable difference between the values of ΔH_{exo} and ΔH_{endo} , which in a general case is explained by the appearance of additional "sources" of energy in the crystalline lattice of samples used (owing to the generation of defects). We assume that in the case of cooling and heating the DKDP samples with a small number of thermal cycles ($n \leq 5-10$), the corresponding transition heat values (ΔH_{exo} and ΔH_{endo}) may be presented as follows:

$$\begin{cases} -\Delta H_{\text{exo}} = -\Delta H_t + \Delta H_{\text{pl}} + \Delta H_{\text{el}} \\ +\Delta H_{\text{endo}} = +\Delta H_t + \Delta H_{\text{pl}} + \Delta H_{\text{el}} \end{cases} \quad (1)$$

where ΔH_t is the true transition heat associated exclusively with the rebuilding of the structure of a DKDP ideal crystal; ΔH_{pl} is the plastic deformation heat released on the friction of domain walls against each other owing to an extremely low mobility of the domains in the DKDP crystal [2]; and ΔH_{el} is the heat, into which the "elastic energy" of the domain walls might transform (i.e., the energy released on the elastic interaction of the domain walls). Since the heats ΔH_{pl} and ΔH_{el} are evolved both on cooling and on heating the samples, then a positive sign is given to them in both equations of the system (1). The system of equations (1) describes qualitatively correct the behavior of the transition heat in the DKDP crystal both in the endoeffect and in the exoeffect with a small number of thermal cycles.

As the number of thermal cycles increases up to $n \sim 80$, the sample is overloaded by nonequilibrium point defects and dislocations, localized on the domain boundaries [3]. As a result, the mobility of domains becomes virtually equal to zero.

Under these conditions, the plastic deformation energy ΔH_{pl} , which has earlier been released owing to the friction of domains, now must dissipate on the formation of cracks in a sample. Therefore, the sign of the value of ΔH_{pl} is reversed to minus (which means the absorption of energy). As regards the "elastic energy" of domain walls, ΔH_{el} , so its value, with a large number of thermal cycles, becomes negligibly small as compared with ΔH_{pl} , because of a strong decrease in the effective thickness of domain walls.

Taking into account the remarks thus made, with a large number of thermal cycles ($n > 80$), the system of equations (1) transforms as follows:

$$\begin{cases} -\Delta H_{\text{exo}} = -\Delta H_t - \Delta H_{\text{pl}} \\ +\Delta H_{\text{endo}} = +\Delta H_t - \Delta H_{\text{pl}} \end{cases} \quad (2)$$

Hence, it is easy to evaluate the mean value of ΔH_{pl} , energy of plastic deformations (dielectric losses) in the DKDP crystal, which, while taking into account the tabular data, amounts to $\langle \Delta H_{\text{pl}} \rangle \approx 0.33$ J/g. Assuming the contribution of ΔH_{pl} to the total transition heat with the

initial thermal cycles to be the same as at $n > 80$, we obtain a solution of the system of equations (1) in relation to the value of $\Delta H_{el} = 0.16$ J/g at $n = 2, 3$. Already at $n = 4$, the value of ΔH_{el} decreases substantially and amounts to about $\Delta H_{el} = 0.04$ J/g. At $n > 5$, the contribution of ΔH_{el} to the transition heat becomes virtually equal to zero.

Let us note that in the first thermal cycle ($n = 1$) the contribution of ΔH_{pl} may be neglected as compared with that of ΔH_{el} , since the crystals are virtually without defects. There, assuming at $n = 1$ that $\Delta H_{pl} \ll \Delta H_{el}$, we obtained $\Delta H_{el} = 0.17$ J/g.

The values of ΔH_{pl} and ΔH_{el} , calculated from the experimental data, allow for estimating the energy of the domain wall (W') in the DKDP crystal. Since the mean size (radius) of domains in the DKDP crystal $r = 1000$ Å [1], then energy of the domain wall, which is the surface energy, amounts to $W' = \Delta H_D / S \approx 40$ erg/cm² at $n = 2, 3$, where $\Delta H_D = \Delta H_{pl} + \Delta H_{el}$, while S is the total surface of all the domains in 1 g DKDP. When the number of the thermal cycles increases $n > 5$, the value of W' somewhat decreases, and amounts to $W' \approx 25$ erg/cm². The estimations of the energy of the domain walls in the DKDP crystal are quite consistent with the literature data [1, 2].

For the KDP crystals (see Table, Fig. 1) the system of equations of the energy balance with any number of thermal cycles, describing the experimental results, will have the following form:

$$\begin{cases} -\Delta H_{exo} = -\Delta H_t - \Delta H_D \\ +\Delta H_{endo} = +\Delta H_t - \Delta H_D \end{cases} \quad (3),$$

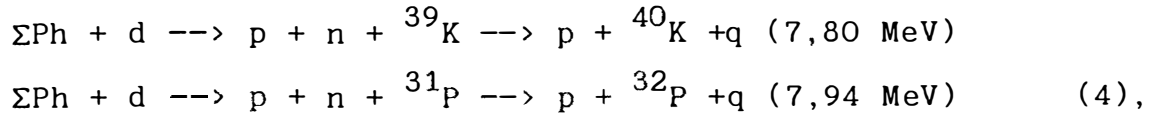
where $\Delta H_D = \Delta H_{pl} + \Delta H_{el}$ represents the energy of the domain wall, which is equal to the sum of the energies of plastic and elastic deformations. The sign "minus" before the values of ΔH_{pl} and ΔH_{el} in the system of equations (3) means that there is no evolution of the energy of plastic and elastic deformations, since the energy is consumed obviously for the rotation of domains, whose mobility in the KDP crystal is approximately by 6 orders of magnitude higher than that in the DKDP crystal [2]. This is just the cause why during 82 thermal cycles the value of ΔH_D varies but slightly - from 0.95 J/g (at $n = 1$) to 0.73 J/g (at $n = 82$).

In distinction from the DKDP crystal, the KDP crystal exhibits a distinctly pronounced hysteresis loop at low frequencies, owing to which the magnitude of dielectric losses, i.e. that of the electric energy of domains, transforming into heat, should be in the case of KDP substantially higher than that in the case of DKDP, which is just observed in the experiment.

Thus, the experimental data obtained with the control KDP samples indicate that on the thermocyclation of these crystals in the vicinity of T_C there is no mechanism of the evolution of the energy of elastic and plastic deformations available, whose presence has been established for the DKDP crystals. It is obvious that such a distinction in the behavior of isomorphic ferroelectric crystals is associated only with the substitution of hydrogen in the KDP crystal for deuterium in the DKDP crystal, inasmuch as other structural characteristics of these crystals are very close to each other. Yet the absence of the channel for the release of the elastic energy of domain walls in the KDP crystal cannot be explained by a purely isotopic effect, because the presence of that effect leads only to a change in the Curie point and the transition heat, and does virtually not affect the elastic characteristics of domains (with the exception of their mobility, which is not an elastic characteristic in a general sense). Therefore, it is possible to suppose that the nature of the difference in heat evolution in the DKDP and KDP crystals is associated with the special properties of deuterium nuclei in the DKDP, which are not possessed by the protons in the KDP crystal.

4. Discussion

In the earlier studies [4,5], we had detected in the DKDP crystals the generation of the products of the nuclear dd-fusion (neutrons and tritium) on the phase transition through the Curie point. In the DKDP crystalline lattice, in addition to the processes leading to the generation of neutrons and tritium, there exists a possibility of the coherent transmission of a virtual neutron from the deuterium nuclei interacting with the giant fluctuations of the density of elastic energy, to neighboring acceptor nuclei (^{39}K , ^{31}P , etc.) [6]. If such be the case, then, on the phase transition through the T_C , the total transition heat would undergo changes due to the appearance of an additional heat source in the DKDP lattice. In this case, the following exoenergetic reactions might be one of the possible heat evolution channels:



where $q=7.80 \text{ MeV}$ and $q=7.94 \text{ MeV}$ correspond to the energy of the neutron binding in the nuclei ${}^{40}\text{K}$ and ${}^{32}\text{P}$, respectively [7]. Now, the "splitting up" condition of a deuteron in the $\Sigma\text{Ph}+d$ reaction will be $E_{\Sigma\text{Ph}} > 2.22 \text{ MeV}$ -

that is, the multiphonon excitation energy must be greater than the deuteron binding energy. The process diagram is presented in Fig.4. In our opinion, the presence of the mechanism of the evolution of the elastic energy by the domain walls in the DKDP crystals and its absence in the KDP crystals is associated just with a possibility of the nuclear reactions of the type (4) in the DKDP crystalline lattice on the splitting up of deuterons interacting with the giant fluctuations of the density of the elastic energy of domain walls, - i.e. with the coherent multiphonon excitations arising on the concentration of elastic energy in separate domains.

Now let us consider in a general form the process of interaction of the elastic energy flux with a high-disperse crystalline medium, in particular, with the system of DKDP domains. We will assume that when crystalline particles have attained a sufficiently small size (r_{crit}) and a certain energy supply rate with the pulse mechanical loading, the absorption of elastic energy becomes of a quantum character. This means that the whole portion of elastic energy to be supplied to a particle will be absorbed by each of its atoms not uniformly, but will rather be concentrated in separate microregions of particles, which we have earlier called as "supercondensates" (SC) [8,9].

For the description of elastic processes occurring inside particles, we introduce a coefficient β , which represents the portion of elastic energy, absorbed by a particle, from the whole amount of energy $E_e = \beta E_t$ to be supplied to that particle (where E_t is the total power of mechanical effect, supplied to a unit mass of crystals, or specific power applied). From the physical standpoint the coefficient β represents a probability of the excitation of a phonon subsystem in the particle subjected to the mechanical effect. For the description of the processes of concentration of elastic energy we introduce a coefficient α of the transformation of elastic energy into that of the optical phonons of the crystal lattice with a Debye frequency ω_D , the coefficient representing a probability of the excitation of phonon modes at the frequency ω_D in a particle. In the first approximation that coefficient may

also be considered as a probability of concentration of optical phonons in the SC in a particle with the size $r < r_{crit}$ ($r_{crit} \approx 10^{-5} - 10^{-4}$ cm) under the conditions of its spherically-symmetric compression. When the particles attain the size $r \approx r_{crit}$ (when the conditions are provided for the spherically-symmetric compression of particle), the elastic energy to be transmitted to the particle is transformed into the energy of phonons. The latter are concentrated toward the symmetry center of the particle in the form of a converging elastic wave [8]. This process is carried into effect when the particle ceases to be transparent for optical phonons at a frequency of ω_D - i.e., when its size diminishes to $r_{min} \leq r_{crit}$, corresponding to the condition of the parametric resonance of the system at its natural frequency of $\omega = \omega_D$ [10]:

$$r_{crit} \approx \frac{\pi (v_s \cdot c)^{1/2}}{\alpha \omega_D} \quad (5)$$

where v_s is the average sound velocity in a crystal, c is the light velocity, and ω_D is the Debye frequency of the given crystal. Since the motion of the converging elastic wave is known to be coherent, the concentration of the energy of optical phonons may provide supercondensate in the particle only in the case when its size $r \leq r_{crit}$.

On the basis of suggested approach the conditions for the concentration of elastic energy in the crystalline particles with the size $r < r_{crit}$, in particular, for the case of "rigid" concentration (i.e. at $E'_e \leq E_{Ph}(\omega)$, where E'_e is the giant fluctuation of the density of elastic energy, and $E_{Ph}(\omega)$ is the density of the energy of optical phonons with a frequency ω), when the value of α is close to 1, may be written as follows:

$$\left. \begin{aligned} E'_e &= \alpha^2 E_{Ph}(\omega) \\ \alpha E_{Ph}(\omega) V &= W_s \end{aligned} \right\} \quad (6)$$

whence $\alpha = W_s / E_{Ph}(\omega) \cdot V$, where V is the volume of a particle having radius r_{min} , and W_s is the SC energy. The energy balance of the phonons concentration process may be expressed in terms of the parameters of an elastic wave in the particle with the radius r_{min} , using the relationship (6), i.e. $E'_e = \alpha^2 E_{Ph}(\omega)$. In this case, we take

into consideration that the energy increment per unit surface of the particle with the radius r_{\min} for the time $\Delta\tau$ is determined as follows [11]:

$$\Delta W_f = 16\pi \cdot \rho \cdot V_s \cdot \omega \cdot a_r \cdot da_r \cdot r \cdot dr \cdot \Delta\tau \quad (7),$$

where ρ is the crystal density; a_r is the amplitude of an elastic wave at a distance r from the surface of the particle; and ω is the frequency of the elastic wave. The increment in the total energy of phonons in the same particle of the crystal with the lattice of the NaCl type may be written in the form [12]:

$$\Delta W_{Ph}(\omega) = \frac{3(K-1) \cdot \hbar \cdot \omega}{(2r_0)^3} \cdot 4\pi r^2 dr \quad (8)$$

where \hbar is the Plank constant, $(2r_0)^3$ is the volume of an elementary cell, and K is the number of particles in the elementary cell ($K=27$). Equating the expressions (7) and (8), while taking into account the conditions (6), we obtain the following equation for the energy balance of the phonons concentration process in the particle with the radius r_{\min} :

$$\begin{aligned} 16\pi \rho V_s \cdot \Delta\tau \int_0^{\omega_D} \int_0^{r_0} \int_0^{r_{\min}} \omega \cdot a_r \cdot r \cdot d\omega \cdot da_r \cdot dr = \\ = \alpha^2 \frac{3\pi \cdot (K-1)\hbar}{2r_0^3} \cdot \int_0^{r_{\min}} \int_0^{\omega_D} r^2 dr \cdot d\omega \quad (9) \end{aligned}$$

where the integration over the elastic wave amplitude is carried out in the range from 0 to r_0 , i.e., to the maximum possible value of the amplitude of the elastic wave in a crystal, which is equal to the lattice constant r_0 . Now, the integration over the elastic wave frequency (that is, over the frequency of phonons) is carried out in the range from 0 to the maximum possible frequency of phonons in the crystal, which is equal to the Debye frequency ω_D . It is easy to show that the time interval $\Delta\tau$

in the relationships (7) and (9) amount to $\Delta\tau = \frac{16\pi^2 r_0}{\alpha \cdot V_s}$

[12], and is, in the physical sense, the time of the maximum atomic shift, i.e., the time which is required for the elastic wave to attain the particle symmetry center

(i.e., to shake loose all the atoms of the particle), at which the oscillations amplitude is maximum and, as has been indicated above, is equal to the parameter of an elementary cell, r_0 .

From the energy balance condition (9), an expression is derived for a possible particle size:

$$r_{\min} = \frac{\omega_D^2 \cdot (2r_0)^3 \cdot \rho \cdot r_0^3}{2 \alpha \cdot (K-1) \hbar \omega_D} \quad (10).$$

Let us note that the value of $2(K-1) \hbar \omega_D / r_0^3$ is the equilibrium modulus of dilatation, B_0 , of a crystal, which can be expressed by the terms of the energy of optical phonons in an elementary cell having the volume $V=r_0^3$ [12]:

$$B_0 = \frac{2(K-1) \hbar \omega_D}{r_0^3} \quad (11).$$

Then the expression (10) for r_{\min} may be represented in the form:

$$r_{\min} = \omega_D^2 / \alpha L, \quad (12)$$

where the introduced value of L is determined as:

$$L = B_0 / \rho (2r_0)^3 \quad (13).$$

Representing a combination of fundamental parameters of the crystal, the value of L (the L factor) has the sense of a limit possible specific elastic energy density concentrated in the particle under the conditions of its spherically-symmetric compression. In other words, this is the density of the energy that is required for overcoming all the Coulomb (electromagnetic) bonds in 1 g of the crystal under conditions of its spherically-symmetric compression. The consequence of that is the transition of the crystal into the state of neutron matter (e.i. degenerated neutron Fermi gas [13]) having the density of $\rho \approx 10^{14}$ g/cm³.

A rough estimation of the SC energy for a particle having the radius r_{\min} leads to a value of $W_s \approx 10^7$ eV. This enables us to consider the SC as a virtual electromagnetic excitation of some nucleus which is found at the center of the symmetry of a crystalline particle having the radius r_{\min} . In this case, the SC energy per nucleon (W'_s) may be found from the equation of state of degenerated neutron gas [13], taking into account that the pressure in the SC is determined by the L factor:

$$W_s' = \frac{3}{5} (3\pi^2)^{2/5} \frac{\hbar^{6/5}}{m_n^{3/5}} (\alpha L)^{2/5}, \quad (14)$$

where m_n is the neutron mass.

At $r \leq r_{\text{crit}}$, it is supposed that on the SC annihilation its energy in the form of virtual γ -quanta is transmitted to the ions of a surrounding lattice. In this case, the effective process of the rupturing of bonds in a particle becomes possible only on the surface of a sphere with the radius r_{min} , surrounding the SC [8]:

$$r_{\text{min}} = c \hbar / \alpha U_0, \quad (15)$$

where U_0 is the cohesive energy of the crystal. Since $0 < \alpha \leq 1$, then the expressions (12) and (15) at $\alpha \ll 1$ represent a quantum comminution limit of crystals exclusively under the effect of elastic forces.

From the second condition of "rigid" concentration (6), it is possible to derive an expression for the probability of the concentration of elastic energy in a particle having the size $r \leq r_{\text{crit}}$ [9]:

$$\alpha \approx \frac{1}{\pi^{5/2}} \frac{m_n c^2}{(\hbar \omega_D)^2} (\hbar m_n)^{1/2} E_e^{1/2}, \quad (16)$$

In this case, the coefficient β , representing a portion of the elastic energy from the whole amount of the energy applied ($E_e = \beta E_t$), is expressed as follows:

$\beta \approx E_f \cdot V_e / E_f \cdot V = 4\pi r_{\text{min}}^2 \cdot H / 4/3 \pi r_{\text{min}}^3 = 3 H / r_{\text{min}}$, (17)
 where E_f is the average density of energy in a particle having the size r_{min} ; V_e is the volume of the elastic layer in the particle; H is the layer thickness; and V is the volume of the particle.

The above relationships allow one to give a sufficiently strict description of the processes of the interaction of the elastic energy flux with a high-disperse crystalline medium. In particular, the suggested approach permits one to calculate the contribution of the elastic energy of domain walls to the total heat of the phase transition in the DKDP crystal. We assume that on the splitting up of the DKDP crystal into domains with the size of $r \approx 1000$ Å at the ferroelectric phase transition point (really, in the vicinity of the T_C with the width $\Delta T \approx 3K$), the elastic energy of domain walls may concentrate inside separate domains.

The process results in the creation of high-energy

fluctuations (supercondensates) inside the domains. The system of domains in the vicinity of the T_C may be considered as a system of particles subjected to the effect of the external elastic energy for short periods of time (about 10^{-9} - 10^{-6} s), which is analogous to the dispersion of an initial crystal into particles with the size $r \approx 1000$ Å. The supplied specific power (E_t) of the process of the concentration of energy in domains with the size $r \approx 1000$ Å will be determined as $E_t = W'S'/\rho V'$, where $W' = 40$ erg/cm² is the energy of the domain wall in the DKDP crystals; S' is the domain surface energy with the radius r ; V' is the domain volume, and ρ is the density of the DKDP crystal. From the relationship (17) we determine the coefficient $\beta = 3H/r = 9 \cdot 10^{-2}$, where $H \approx 30$ Å is the thickness of the domain wall, and $r = 1000$ Å is the average size of the domain in the DKDP crystal. The magnitude of the elastic energy of the domain walls $E_e = \beta E_t$ is determined from the relationship $E_e = 9H W'/\rho r^2$.

From the above relationships (16) and (14) we determine the coefficient $\alpha = 0.23$ and the energy of SC, $W'_s = 1.8 \cdot 10^{-5}$ erg - that is, approximately 11 MeV/nucleon.

The quantity of SC, i.e., the number of coherent multiphonon excitations (ΣPh) arising in the DKDP domains during the phase transition, while taking into account the condition (6), - amounts to $N_s = E_e/\alpha W'_s = 1.2 \cdot 10^{11}$ SC/g. transition. Assuming that the formation of one SC leads to the carrying into effect of one reaction of the type (4), we obtain the value of $\Delta Q = N_s q$ for the contribution of the elastic energy of domain walls to the total transition heat, or, taking into account the relations (14), (16) and the expression for E_e , in the general form:

$$\Delta Q = 5\pi^{3/2} \left[\frac{\hbar^9 \omega_D^{28}}{m_n^{15} c^{28} L^4} \right]^{1/10} \cdot q \cdot \left[\frac{9 H W'}{\pi r^2} \right]^{3/10} \quad (18)$$

where $\omega_D = 6 \cdot 10^{13}$ Hz is the Debye frequency of the DKDP crystal; $L = 2 \cdot 10^{33}$ erg/cm³g is the value of the L factor of the DKDP crystal; q is the reaction heat (4); $\rho = 2.35$ g/cm³ is the density of the DKDP. The calculation of ΔQ with the formula (18) gives the value of $\Delta Q = 0.15$ J/g, which is fairly well consistent with the experimentally determined contribution of the elastic energy of the domain walls,

ΔH_e , to the total heat of the phase transition in the DKDP crystals.

5. Conclusions

In conclusion, we point out that the energy ΔQ is by no means none "excessive", since it does not exceed the value of the total surface energy of the domain walls in the DKDP crystal. The choice of the value of $r \approx 1000$ Å as the domain size in the DKDP crystal, which has been used in the calculations, should be recognized as reasonable, since its estimations from the relationship (12) lead to the same value of $r_{\min} \approx 1000$ Å. It will also be essential to emphasize that in the KDP crystals the reactions of the type (4) are impossible, since no nuclei of the elements with a low neutrons bonding energy are present in them. As a result, in the case of the KDP crystals the elastic energy of the domain walls cannot be evaluated in the form of heat.

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Table.
Heat effect parameters in DKDSP and KDP crystals at $V_1=4,8$
K/min^{*})

Crystal type	Cycle number	Exoeffect (cooling)			Endoeffect (heating)		
		$\Delta H, J/g$	T_m, K	$\Delta T_{1/2}, K$	$\Delta H, J/g$	T_m, K	$\Delta T_{1/2}, K$
KDP	1	3,52±0,11	118,8	6,1	1,63±0,05	124,4	2,4
	2	4,10±0,12	119,3	6,0	1,80±0,06	124,4	2,8
	.						
	.						
	81	3,10±0,10	119,0	5,0	1,88±0,06	124,0	2,5
	82	3,24±0,10	119,5	6,0	1,61±0,05	124,1	2,4
DKDP (97%)	1	5,90±0,10	216,3	3,1	6,25±0,12	218,1	2,5
	2	5,43±0,16	216,3	3,2	6,41±0,19	218,1	2,5
	3	5,62±0,17	215,8	3,3	6,60±0,23	218,7	2,6
	4	5,69±0,12	215,8	3,2	6,43±0,15	218,5	2,5
	.						
	.						
	81	6,27±0,19	214,8	3,9	5,56±0,17	219,3	3,0
	82	6,10±0,18	214,9	4,0	5,49±0,18	219,3	2,8
DKDP (70%)	1	4,68±0,11	200,1	6,5	4,95±0,12	206,9	4,3
	2	4,30±0,13	200,4	6,3	5,11±0,15	206,9	4,2

- *) ΔH - experimental value of the phase transition heat;
 T_m - temperature position of the peak's maximum
 $\Delta T_{1/2}$ - halfwidth of the peak

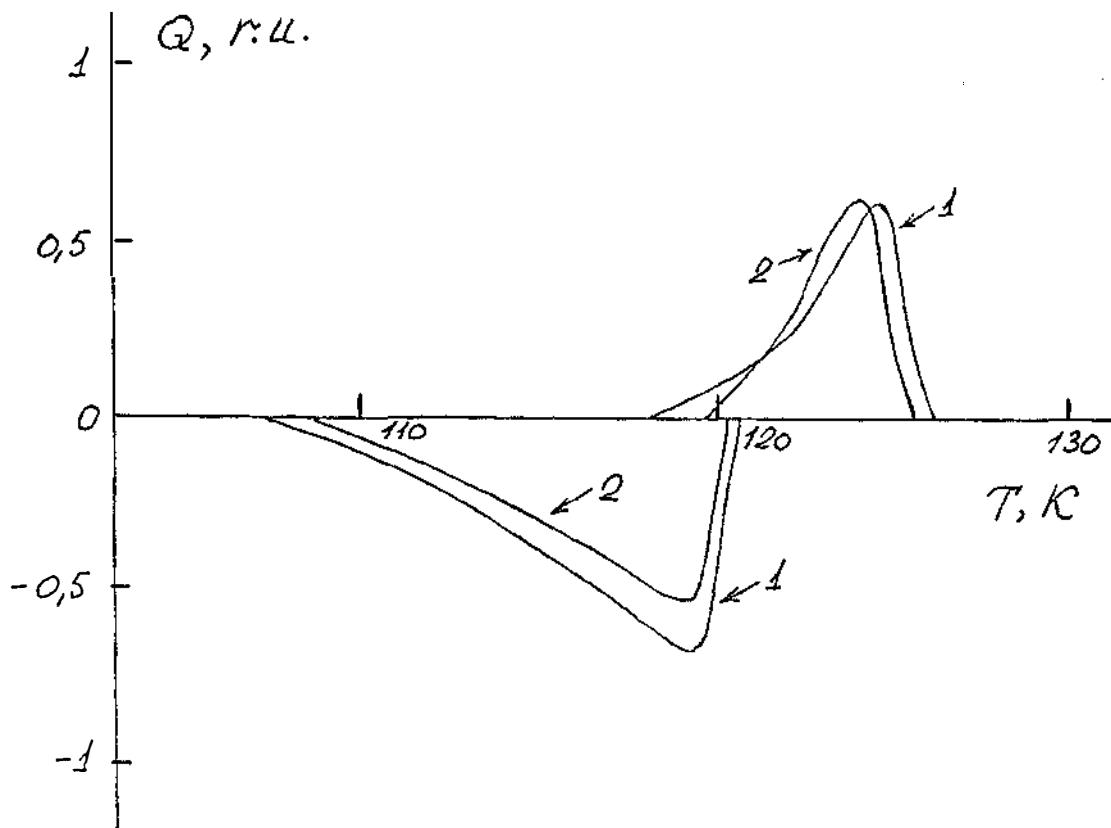


Fig.1. Heat effect kinetics on the phase transition in KDP crystals: 1 - cycle 2; 2 - cycle 82; v_1 4,8 K/min.

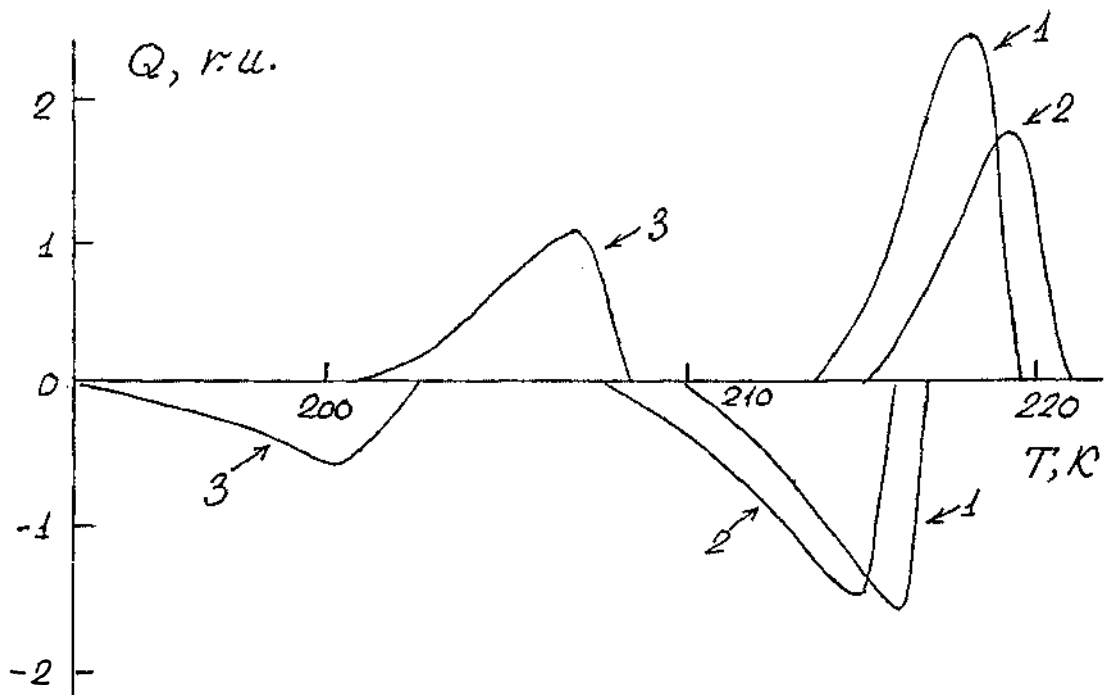


Fig.2. Heat effect kinetics on the phase transition in DKDP crystals:
 1 - (97 % deuterium), cycle 2;
 2 - (97 % deuterium), cycle 82;
 3 - (70 % deuterium), cycle 2; $v_1=4,8$ K/min.

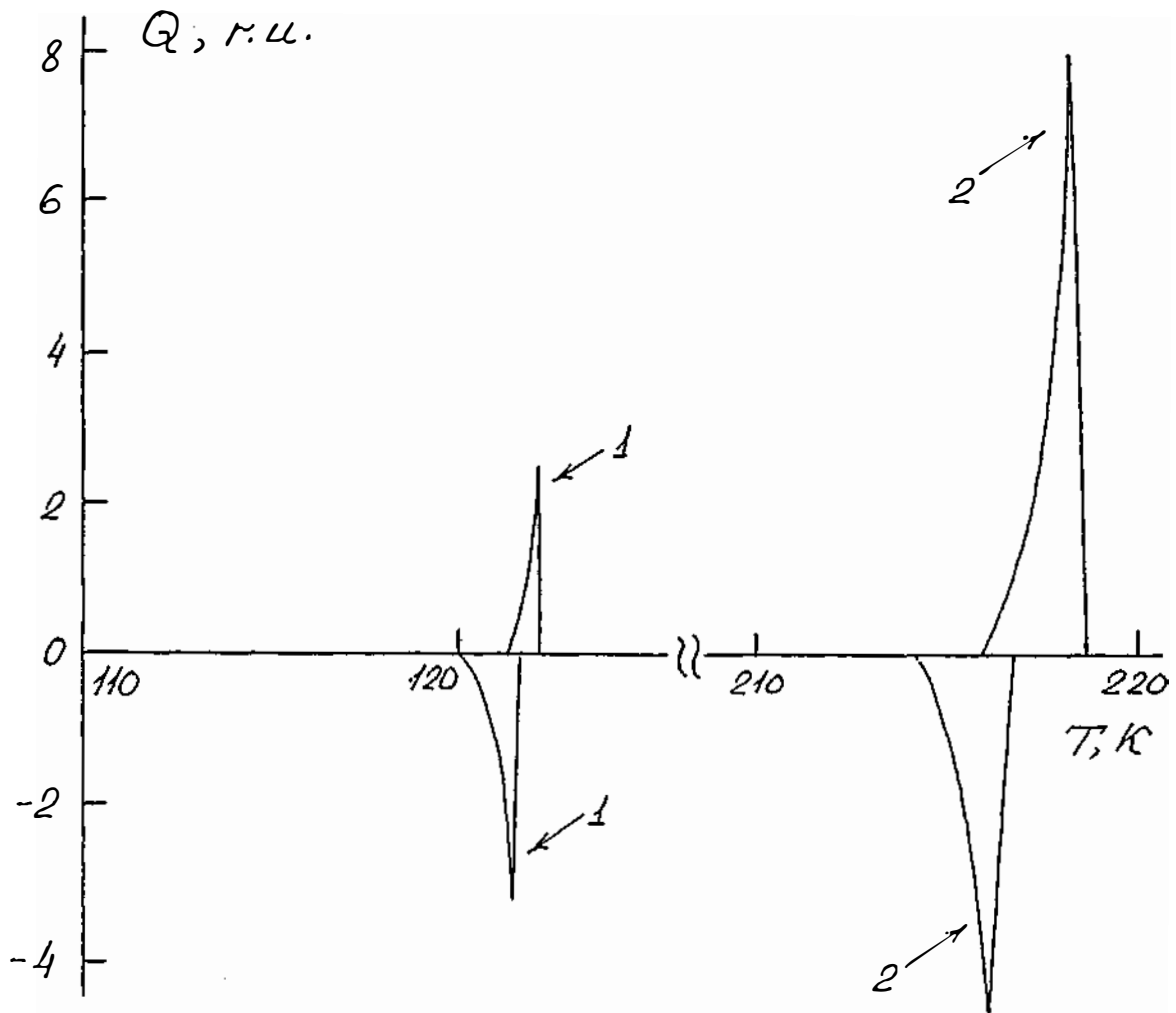


Fig.3. Heat effect kinetics on the phase transition in KDP crystals at $n=3$ (curve 1) and in DKDP crystals at $n=3$ (curve 2); $v_2=0,5$ K/min.

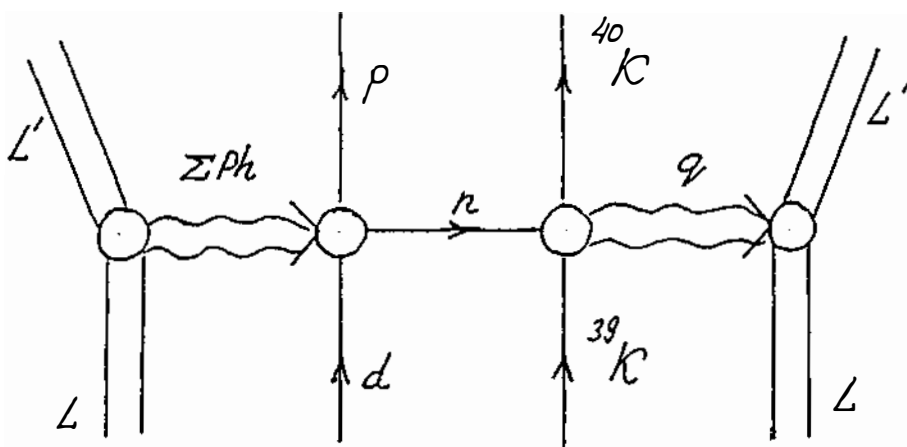


Fig.4. Feynman - like diagram for the proposed coherent production (the evolution of domain walls elastic energy) in DKDP crystal, which is responsible for reaction (4): L and L' - DKDP domain in non-excited and excited state respectively.