

Metastability: New Approaches

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In relatively recent reviews by Martynov G.A. [1], Rudoy Yu. G. and Sukhanov A.D. [2] attention has been paid to such still unsolved problems of statistical mechanics as:

1. How are the quantum-mechanical and statistical fluctuations connected?
2. What is the reason of a phase transition, what are the causes of a loss of stability by a master phase in the supercritical region?
3. Why does thermodynamics describe the metastable states and statistical mechanics does not? What are the limitations that exclude metastable states from consideration in the Gibbs statistical mechanics?

By definition, the phase transition is jumping of the system structure accompanied by catastrophical changes of some physical characteristics. But the Gibbs distribution for finite systems doesn't imply even any indications of phase transitions and doesn't contain information about any metastable states.

Now statistical thermodynamics considers more adequately than statistical mechanics integral characteristics of macroobject absent in principle in any microobjects (such properties are described, for instance, by intensive thermodynamic parameters).

After summarizing the experience of the Gibbs statistical mechanics exploitation the absence of the final answer for the question about the causes of phase transitions and a loss of stability by a master phase in the supercritical region puts the idea about limitations in its basic axioms not permissive to reveal these causes. A possibility of an incomplete correspondence of the results of statistical mechanics and statistical thermodynamics was indicated by A.G. Lorentz in 1912. I am citing according to [2]: "It could be concluded that at the present moment the applicability ranges of both methods do not completely coincide though they have an extensive general part." Such a situation is the same up to now.

Later on the inevitability of such inconsistency was indicated by V.A. Fock and N.S. Krylov (1950): "One can assume that between the macroscopic characteristic and a usual microscopic description there exists some kind of additional property similar to that appearing at a classical description according to quantum mechanics. A more precise location of the system inside the phase range with the macroscopic state is impossible without the disturbance of the system macroscopic characteristic".

In fact, the system macroscopic state can be preset only with an accuracy to the system interaction with the thermostat energy. At a precise calculation of the system state in the Schrodinger operator the interaction of charged particles both within the system and with the thermostat charged particles is presented by the Coulomb forces and we do not have a rule according to which the interaction with the thermostat can be neglected. Moreover, the interference effects of the wave equation can radically change the picture of the microstates multiplicity for a system immersed into the thermostat as compared with the isolated system microstates multiplicity. Here it should be kept in mind that the number of particles in the thermostat tends to infinity and the thermostat behaviour is absolutely stochastic.

At last the words of R.B. Laughlin (Nobel Prize Laureate of 1998): "I suspect that all the most important problems in physics including quantum gravitation are in their essence connected closely with such collective phenomena that cannot be derived from the properties of the comprising the system components".

These opinions give reasons to consider the efforts directed towards putting into conformity statistical and thermodynamic descriptions actual and necessary.

The clear and exact definition of the metastable state notion is absent in literature, the causes of its arising and instability with respect to finite perturbations are not found out, and it is not indicated by what it differs from a stable one.

The problems of metastability and phase transitions are connected closely as the metastable systems always stop their existence via the phase transition. Therefore the understanding of the causes of the metastability appearance can be helpful for revealing the phase transitions reasons .

From the fact of the metastable phase existence at any long time intervals at suppression of all external perturbations it follows that it is in a statistical equilibrium because all the relaxation processes during the times of its existence come to end.

The phase transition phenomenon is always accompanied by change of spatial symmetry and structure at melting and of structure at the transition fluid-gas.

The potentials of interaction are responsible for the system structure, so one can suppose that they change their structure sharply during phase transition (the first "prompt" of nature).

The comparison of the radial distribution functions for a crystal and a fluid for all the substances without any exception results in a conclusion on the appearance of an excess of molecules between the 1st and 2nd coordination spheres for a fluid (the secondary structure) [3]. This is distinctly seen on the experimental curves for the paired distribution functions of particles in the fluid [4]. Knowing that the distribution radial function under the zero approximation is proportional to the factor $\exp\{-U(R)/kT\}$ ($U(R)$ is the potential of molecule paired interaction) [5], we come to a conclusion that at melting the paired coefficient of interaction for molecules undergoes a change from the potential with one minimum to the potential with two minima. (The second "prompt").

Summarizing the aforesaid we can conclude that localization of the immersed into the thermostat system with an arbitrary large accuracy is impossible because of the remotely acting Coulomb forces and "effective" potentials of interaction (other ones are out of question) depend on the thermodynamical parameters and just they assign system phase state.

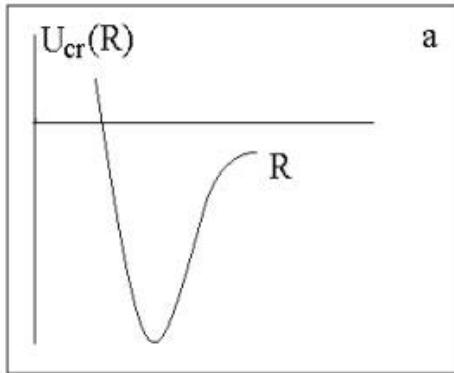


Fig.1. A potential of a paired interaction in a crystal.

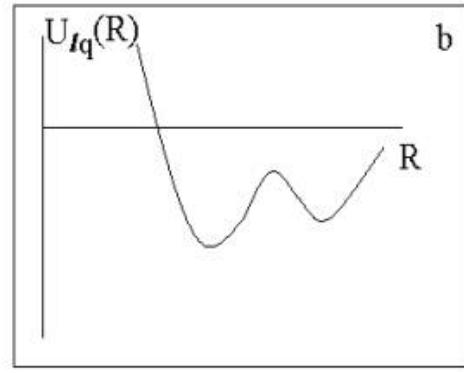


Fig.2. A potential of a paired interaction in a fluid.

To deduce a canonical distribution the system quasi-isolation was needed. This problem was solved with the application of the requirement of the intermolecular forces short action that resulted in the conditions

$$I \ll N_S \ll N_W, \quad (1)$$

$$U_{SW} \ll H_S \ll H_W, \quad (2)$$

where N_S, N_W are numbers of particles in the system and in the thermostat, correspondingly;

U_{SW} – is the energy of the system and thermostat interaction; H_S – is the energy of the system;

H_W – is the energy of the thermostat.

Point out that the molecules short-range interaction the most frequently used in problems of statistical mechanics is the interaction of unstructured point particles and it's the same for all possible phases. Interactions of other types are considered near never.

The requirement $U_{SW} \ll H_S$ makes the system dynamics independent on the thermostat state and excludes metastable states from the multiplicity of the equilibrium ensemble microscopic states. This condition is very strict and inapplicable to fundamental remotely acting interactions what makes the statistical description of system composed, in general, of charged particles wanting.

Let us substitute the rigid requirement (2) by a less rigid one:

$$U_{SW} \sim H_S \ll H_W. \quad (3)$$

For systems of macroscopic sizes this means a remote action. A quasi-closed in this case can only be a system of an infinite size, i.e. the thermostat.

So, let condition (3) be fulfilled. As $U_{SW} \ll H_W$, the thermostat can be considered a quasi-isolated system for which the Gibbs function $f_W^G(\{q_w\}, \{p_w\}; T_w)$ exists, where q_w are the coordinates of thermostat particles the; p_w momentums; T_w are the is the temperature.

The quasi-isolation condition for remotely acting forces is fulfilled only at $N_w \rightarrow \infty$, $V_w \rightarrow \infty$, and the function f_W^G , depending on an infinite number of variables has the formal character.

The particles motion equations in the system and in the thermostat due to (3) has the form of

$$\begin{cases} p_s = -\frac{\partial H_s}{\partial q_s} - \frac{\partial U_{sw}}{\partial q_s} \\ q_s = \frac{\partial H_s}{\partial p_s} \end{cases} \quad (4)$$

$$\begin{cases} p_w = -\frac{\partial H_w}{\partial q_w} \\ q_w = \frac{\partial H_w}{\partial p_w} \end{cases} \quad (5)$$

At remotely acting interactions the time between collisions of any two particles in the system is inversely proportional to the particles number

$$\tau_s \sim N_s^{-1}, \quad \tau_w \sim N_w^{-1}, \quad (6)$$

τ_s, τ_w is the mean time between the collisions of any two particles in isolated systems S and W .

In view of the relationship $N_s \ll N_w$ we have $\tau_s > \tau_w$, therefore equations (4) can be averaged over the time interval $\tau(\tau_w \ll \tau \ll \tau_s)$. By definition the variables q_w and p_w are random ones. The time between the collisions of the system with the thermostat due to the interaction of the system S with the whole thermostat is about τ_w . The time τ is not the time when a thermal equilibrium is established between the system and the thermostat. This is a typical time of the particles interaction energy redistribution in S between each other due to a change of the S with the thermostat interaction. As the thermostat is in a complete thermodynamic equilibrium, when all the relaxation processes are over, the thermostat during the time τ is only in the states constituting the equilibrium distribution. The condition of the ergodic hypothesis applicability requires only a short time between the collisions of the system with the thermostat as compared with the time between collisions in S (the observation time), and thus the condition $(\tau_w \ll \tau_s)$ is fulfilled. Using the ergodic hypothesis we substitute averaging in time τ of the motion equations (4) by averaging over the ensemble of systems W presented by the distribution function $f_w^G(\{p_w\}, \{q_w\}; T_w)$. Then

$$\begin{cases} p_s = -\frac{\partial H_s}{\partial q_s} - \frac{\partial U_{sw}(\{q_s\}; T_w)}{\partial q_s} \\ q_s = \frac{\partial H_s}{\partial p_s} \end{cases} \quad (7)$$

The value of $-\frac{\partial U_{sw}(\{q_s\}; T_w)}{\partial q_s}$ gives an average force acting on the particles in S from the side of the

thermostat that is in accordance with the particles motion in S . Averaging over f_s^G is of a formal character, it only indicates that the thermostat should be considered a continuous medium and the value of $U_{sw}(\{q_s\}; T_w)$ should be considered the energy of the interaction of the system S with the field of the thermostat response to the system S external field variation.

The average field ideology demands to relate a part of the interaction of S with the thermostat energy to the thermostat as an average field against which the system moves (renormalization due to the energy count). In particular, if the system is in the thermodynamic equilibrium with the thermostat it is possible but again formally to introduce the distribution function of the combined system $S \oplus W$ $f_{S \oplus W}^G$ and to calculate a particle mean interaction energy in $S \oplus W$.

$$\langle U_{SW}(T) \rangle = (N_S + N_W)^{-1} \iint_{\Gamma_{S \oplus W}} U_{SW} f_s^G d\Gamma_{s \oplus w}, \quad (8)$$

$\Gamma_{S \oplus W}$ is the phase space of the system $S \oplus W$.

The value $E_{SW}(T) = \lim_{N_W \rightarrow \infty} N_W \langle U_{SW}(T) \rangle$ should be related to the thermostat. Then

$$H_{\text{eff}}(\{q_S\}, \{p_S\}; T) = H_S(\{p_S\}, \{q_S\}) + U_{SW}(\{q_S\}; T) - E_{SW}(T) \quad (9)$$

is the effective Hamiltonian of the quasi-isolated system S_{eff} , depending on the thermostat intensive characteristics as on parameters.

The effective Hamiltonian H_{eff} is correlated with the thermostat thermodynamic state (in equilibrium with the system thermodynamic state). A transition to the thermodynamic limit ($N_W \rightarrow \infty$, $V_W \rightarrow \infty$, $N_W/V_W = \text{const}$) is realized in the thermostat before constructing the distribution function f_{eff} . The thermostat state can be characterized besides the temperature also by the intensive parameters $\{\lambda_i\}$ of the external to the system fields which exciting certain degrees of freedom in the system S can change the energy of interaction between the system particles and, consequently, the phase state.

Efficiently, the system S with a limited number of particles N_S has an infinite number of freedom degrees due to the thermostat freedom degrees account. The system is also effectively quasi-isolated from the thermostat (the Hamiltonian H_{eff} does not depend explicitly on the thermostat dynamic variables $\{q_w\}$ and $\{p_w\}$) with the help of the averaging procedure over the thermostat freedom degrees and the energy renormalization. For such an effective system the Gibbs conditions are fulfilled and the system S_{eff} can be represented by the Gibbs effective ensemble

$$f_{\text{eff}}(\{p_S\}, \{q_S\}; T, \{\lambda_i\}) = Z_{\text{eff}}^{-1} \exp \left\{ - \frac{H_{\text{eff}}(\{p_S\}, \{q_S\}; T, \{\lambda_i\})}{kT} \right\}, \quad (10)$$

where Z_{eff} is the statistical sum for the effective system S_{eff} .

Due to the nonlinear connection of the particle dynamics in S with the thermodynamic state the function H can be a many-valued function of temperature, as a result the Gibbs measure becomes a many-valued one over temperature as well.

Note that the correspondence principle is fulfilled as, when neglecting the interaction energy of the system S with the thermostat as compared with the system inner energy, (10) automatically becomes the Gibbs distribution f_S^G .

The condition $N_S \gg 1$ is used nowhere (earlier it was needed for the system to become a quasi-isolated from the thermostat at short-acting forces), therefore H_{eff} can be constructed of the effective paired interaction potentials depending on the system thermodynamic state $\Phi_{12\text{eff}}(|q_2 - q_1|; T)$ presenting the interaction of two molecules with

the account for their interaction with the continuous environment the thermodynamic parameters of which govern the $\Phi_{12\text{eff}}$ dependence on temperature. The environment in its turn depends on $\Phi_{12\text{eff}}$ (self-consistency).

A strict solution of the phase transitions problem under such an approach is the self-consistent problem for determining the interaction effective potentials, radial distribution functions and the medium thermodynamic characteristics. This is a recipe to obtain the Gibbs measures multi-valued over temperature and, as a consequence, the metastable states and phase transitions in the limited system.

The scheme proposed for determining the cause of the metastability and phase transitions appearance presents the feedback principle – the system self-action via a reaction field of the surrounded the system and characterized only by intensive thermodynamical parameters continuous environment in reply to the change of interactions inside the system.

The statement that the thermostat represents a continuous medium for the system is of principal character. Indeed, having extracted the system from the thermostat as the particle enumerable aggregate we cannot take into account interactions with thermostat particles simpliciter because of their infinite number and random values of their coordinates and momentums. The impossibility of characterizing the thermostat by dynamical parameters is principal. So the thermostat is always continual for the system and the interaction of the system with the thermostat is, in principle, the interaction with the reaction field, i. e. the system self-action via continuous environment characterized by only macroscopic parameters. At the stochastization of the thermostat the enumerable set of particles in the

thermostat becomes innumerable continuum. Just therefore the system with the thermostat interaction represents the feedback.

The system size is determined only by the observer capability to extract it from the infinite stochastized set of particles and to describe the dynamics of the N_s interacting particles with account of their interaction with the continuous environment. The account of interacting with the thermostat in form of interacting with the thermostat reaction field in reply to the change of the system external field as it moves (the feedback) puts a nonlinearity into the particles motion equations which is the source of ambiguity of the system effective Hamiltonian on the environment thermodynamical parameters and, consequently, the source of Gibbs measure non-uniqueness.

The cause of phase transitions and metastability states existence in finite systems is the presence of the infinite, stochastized and, consequently, innumerable environment correcting system particles moving according to the feedback principle.

Depending on the feedback structure prevailing in a certain phenomenon the master phase in the supercritical region is either absolutely unstable (the absence of superheated crystals) or unstable relatively to the limited perturbations (a metastable supercooled fluid). The absence of superheated crystalline phases can be easily explained with the models leading to a reconstruction of the potential for the paired interaction from a potential with one minimum to a potential with two minima. At the formation of the second minimum in the paired interaction potential an immediate loss of a crystalline phase symmetry occurs (absolute instability). Statistical disagreement that resulted in the formation of the second minimum at cooling of the fluid, on the contrary, prevents its disappearance for which a coordinated transition of molecules over the energy barrier in some macroscopic region is necessary (a kernel of a stable phase).

A simple cell-like model with a constant volume for a water-like fluid, in which the feedback principle is realized as a molecule interaction with an electromagnetic structure changing when pair interacting with the dielectric environment, has demonstrated the presence of phase transitions and supercooled fluid metastable states, the hysteresis of thermal capacity on temperature and the absence of superheated crystal [6].

Let us remind that at the formation of an hydrogen bond (HB) between water molecules a redistribution of electronic densities occurs so that the molecules take effective charges $\pm Q_{eff}(R)$. As the permittivity depends on the broken the HB molecules number that in its turn is connected with the effective potential via the Boltzmann distribution, a problem of self-consistency arises for the definition of this broken the HB molecules number and the effective potential acting in an elementary cell depending on temperature.

The parametrized interaction of the effective charge with the environment is chosen in form: $W = -[a+bN_2(T)]R$ (a and b are constants characterizing the water molecule, $N_2(T)$ is the number of broken the HB molecules, R is the molecule distance from the elementary cell center).

A numerical solution for the number of broken the HB molecules and two types of potentials in the cell realized at the melting temperature T_m , are given in the figures below.

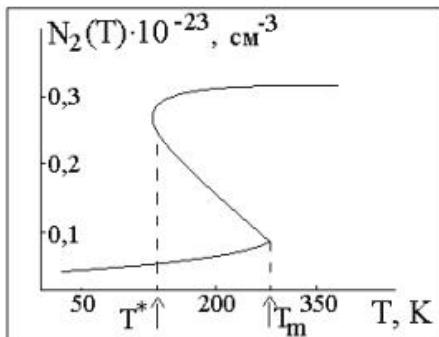


Fig.3. Dependence of a molecule number in a broken HB per unit of volume on temperature.

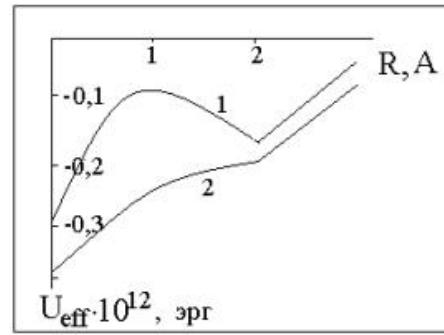


Fig.4. Effective potentials in an elementary cell at melting temperature T_m . 1 is liquid water; 2 is a crystal.

The effective potentials are renormalized, therefore the latent heat of melting is the difference between the mean values of U_{eff} for the crystal and the fluid at the given temperature.

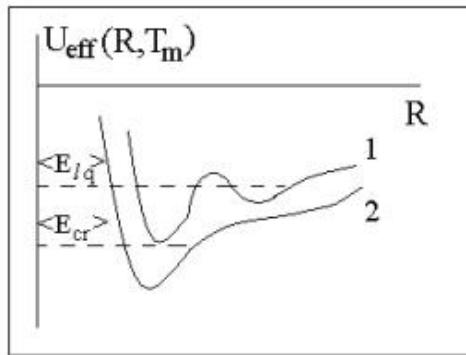


Fig. 5. 1 is a fluid; 2 is a crystal; $\delta Q = \langle E_{1q} \rangle - \langle E_{cr} \rangle$ is the latent heat of melting per one molecule.

The behavior of the heat capacity c_v demonstrates the hysteresis phenomena as the system evolves with changing temperature in accordance with the Le Chatelier principle.

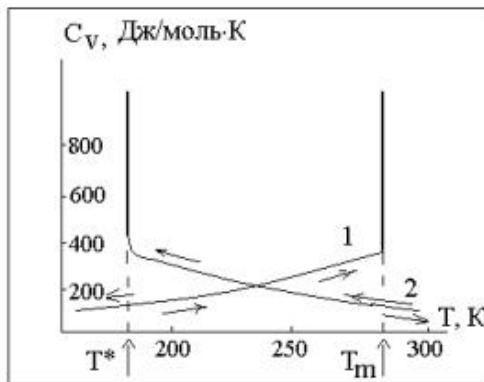


Fig.6. Curve 1: dependence of c_v on temperature at heating; curve 2: the same at cooling. T_m - is the melting temperature, T^* - is the temperature of the fluid maximum supercooling.

At the temperatures $T^* < T < T_m$ the existence of a supercooled fluid is possible.

In spite of the rather rough parametrization of the effective potential and fixing the volume, the melting temperature is found to be 276 K, the temperature of maximum supercooling – 181 K and the latent heat of the phase transition – 1,75 kcal/mol. The consistency with the experimental data is satisfactory. Taking into account the volume change allows to calculate the surface of free energy in space of variables V and T , and it results in a distinctive fold in the melting temperature region, as in Tom's theory of catastrophes.

A model with the feedback allows to manage a phase state via a selective influence by the resonance radiation on the definite freedom degrees responsible for the feedback structure [7]. Directing of phase state via resonance radiation is one of experimental opportunities to check the suggested theory.

The proposed model of metastability is, as we believe, experimentally supported by works [8] and [9]. In [8] it is found that under the action of resonance radiation on the supercooled water droplets the rate of crystal formation increased almost by two orders of magnitude. In [9] the condensation of superheated anthracene vapors was observed within the field of ultraviolet resonance radiation, the point of condensation being shifted in temperature by almost 300 K.

The principle of the feedback as applied to the condensed media leads to an understanding that at changing temperature or density of outer resonance (or coherent) fields, exciting certain selective degrees of freedom, the potentials of molecule interaction change in self-consistency with the variation of these controlling parameters in the joint (system-thermostat) complex. Such nonlinear connections result in the end in instability of the master phase over some varying parameter depending, by no means, on the feedback structure. From the viewpoint of the feedback principle any metastable phase with the help of a certain selective effect, much less than the inner energy of the

system, can be changed into a stable state. For this the existing statistical equilibrium ensuring the master phase stability relatively to limited perturbations should be disturbed.

Let us give now a definition to a metastable state.

The metastable state is possible only for cooperative systems with fluctuations. The fluctuations are the condition necessary but not sufficient. The sufficient condition for the existence of the metastable state is the system self-action via the continuous environment reaction field (the realization of the feedback principle) self-sustained after the removal of the outer causes led to the appearance of this state. Just from this moment the system state becomes the metastable one and it exists only till the moment when the system under the action of outer perturbations goes to the other state. At such a transition the metastable state breaks down.

The cause of the appearance of metastable states is so general that the feedback principle pretends to be one of the main postulates of physics.

Not without argument one can number with such postulates the principle of least action (a method for matter description), the postulate about the geometrical space-time structure (the principle of relativity, conservation laws), the postulate about corpuscular-wave dualism with the principle of uncertainty by Heisenberg-Bohr for coordinate-momentum and energy-time (vacuum, particles, wave function), and, at last, the statistical principle which is of auxiliary character.

All known phenomena in the world except metastable states are covered by this code of postulates. The absence of clear ideas about causes of phase transitions and metastable states nature points to a possible incompleteness of the code of fundamental laws.

The necessity of inclusion metastable systems into phenomena described on basis of main principles leads to understanding that the feedback principle is one of fundamental ones. It transforms the fundamental axioms code into closed one relatively the level of the present physical knowledge and raises the statistical principle to a basic rank.

For description of metastability in the framework of equilibrium statistical mechanics the calculation of the system interaction with entirely stochastized system with infinite number of freedom degrees is required. This requirement is principal and not permitting to extend the system up to nonsensical infinity. So the feedback principle introduces the notion of global entirely stochastized thermostat in which all the real part of matter is immersed and interaction with this thermostat transforms deterministic motion equation into irreversible evolution equations. What is this thermostat? A most promising candidate for the role of a global, common thermostat is vacuum of the Unruh accelerated systems [10]. From the viewpoint of the Unruh effect vacuum has property of ideal potential liquid: moving evenly bimodal detectors don't interact with it and accelerated ones feel a resistance connected with stochastic exchanging momentums with vacuum fluctuations distributed according to the Planck law with a

temperature $T_{\text{vac i}} = \frac{h a_i}{4 \pi^2 c k}$ (a_i - is the detector acceleration, c - is the velocity of light, h - is the Planck constant, k - is the Boltzmann constant). The acceleration of such a detector depends on the detector effective interactions with the environment $a_i = -\frac{1}{m_i} \frac{\partial H_{\text{Seff}}(\{q_S\}; \{p_S\}; T)}{\partial q_{Si}}$, i.e. on the thermodynamic state of the environment, therefore

the thermodynamic temperature can be connected with the effective temperature of the vacuum [11].

According to these postulates the matter moving in the quasi-Euclidean space-time exists in two states: real particles for which the condition $\Delta E \Delta t \geq \hbar/2$ is fulfilled, the interaction among which ensures the motion determinism and the virtual particles for which the Heisenberg-Bohr relationship for the energy-time is disturbed. The connection between the thermodynamical temperature and the effective vacuum temperature (may be not simple) points to the fact the thermodynamical temperature is the macroscopic demonstration of vacuum fluctuations introducing fortuitousness into the world of real particles via the accelerations of multi-level detectors-particles in effective fields.

The strict substantiation of the statistical mechanics, to all appearances, is possible only in the quantum field theory with the Unruh vacuum (the random continual medium, intermixing in a random way real particles systems via the connection of vacuum quantum characteristics with the systems of real particles quantum numbers by the classical quantity – acceleration). In this phenomenon the feedback principle reveals itself in pure form as vacuum is continual in principle. It is an objective source of fortuity, necessary for the existence of statistical laws as objective one's.

The feedback principle supplies with the existence of metastable systems, allows to explain the reasons of phase transitions and points to the connection between thermodynamical and quantum-mechanical vacuum fluctuations as to hierarchical one.

The feedback principle is not only of abstract character. It allows one to formulate certain problems of different systems phase states management. It may be, for example, getting the crystal phase at temperatures larger than

melting temperature in resonant fields exciting selectively degrees of freedom responsible for recovery of torn intermolecular connections or putting a metastable system into a stable state via external resonant radiation violating a statistical balance which provides with master phase stability concerning finite perturbations. Under such transition the front of crystallization must be absent as the transition is realized at once in all the range where the stimulating radiation is present (temporary closing-down of alive cells, high homogeneous crystal mixtures). It may be possible to manage the radioactive nuclei half-decay time if their nature of metastable states is in agreement with the above suggested conception. The feedback principle makes it possible to predict also such exotic phenomena as the dependence of the Lamb shift on temperature and the Kazimir effect of the system under study acceleration.

The feedback principle has not only utilitarian significance allowing to realize causes of phase transitions and metastable states formation and in which way one can manage system phase state, but also a philosophical one. This principle fills the philosophical law of quantity-quality transition with concrete content and shows how macroscopic properties of the system as a whole are transmitted to the microscopic level of interacting elementary system parts not allowing a too large detailed elaboration of the microscopic state in a phase region, determined by the macroscopic characteristic and not allowing self-consistently a violation of it (remember V.A.Fock's statement). Point out, to preset the system microscopic state detailed as a part of thermostat is possible only with an accuracy not beyond the accuracy of determination the system with thermostat interaction energy. Returning to the V.A.Fock's statement, specify: the system microscopic states combined with its macroscopic one are complementary one another characteristics and can't be independent just as coordinates and momentums in quantum mechanics. The last property is a consequence of matter corpuscular-wave nature with an action minimal quant h and is expressed by the Heisenberg-Bohr uncertainty relation. The subsidiarity of the macroscopic and microscopic states is expressed by the feedback principle which doesn't allow to preset the system microscopic state with the absolute accuracy because of its connection with the infinite environment and to set this connection in other way than via the environment reaction macroscopic field in view of the last one's random freedom degrees infinite number.

The feedback principle allows to realize the impossibility of the evolution time reverse as it not only changes the probability of the system being in microscopic combined with the preset macroscopic one states but changes these states theirself consisting them with the environment or the system itself present macroscopic state (self-consistency). So the feedback principle and the statistical principle can be raised to the rank of nature fundamental laws.

Without calling the feedback principle it's also difficult to explain the system evolution orientation from simple to complex. The feedback principle allows to describe how a chance appearance of some macroscopic characteristic sign is carried to the microscopic level and develops. If there is no feedback the appearance and decay of such sign is equiprobable and there is no detailed evolution direction. The feedback violates such a symmetry. Accumulation of such sign on the microscopic level, gradual microstates changing with the environment macroparameters change brings the system, at last, to the instability region on given macroscopic characteristic and, consequently, to phase transition. Quantity converts into quality. It's possible only in systems with feedback.

So the feedback principle is the phase transitions, metastability, evolution, self-consistency of the moving matter.

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