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Волинський національний університет імені
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THE INSTANTANEOUS VALUES OF MAIN THERMODYNAMIC PARAMETERS AND POTENTIALS THAT ARE CHARACTERISTIC TO GIBBS THERMODYNAMIC MICROSTATES

Danylchenko, Pavlo Ivanovich

The equations that combine the instantaneous values of main thermodynamic parameters and potentials (that are characteristic to Gibbs thermodynamic microstates) of the simplest gases and liquids were found. The maximum possible (limit) velocity of matter transfer and the four wave functions and derivatives from them, which can take with certain probability any arbitrary instantaneous values, are used as thermodynamic hidden parameters and variables in these equations. Such gases and liquids can gradually (evolutionally) quasi-equilibrium cool down with self-creation of stable gravitational fields due to electromagnetic interactions of their molecules. In those fields the local values of characteristic intensive parameter are saved in time and corresponding to it characteristic extensive parameter is the same in the whole space at the same time. The electro-magnetic nature of gravitational field in matter was justified. It was proved that hypothetical ideal matter (ideal gas, ideal liquid) in principal cannot self-create gravitational field due to the absence of electromagnetic interaction of its molecules. The dependencies of physical and other thermodynamic characteristics of matter on the hidden parameters and variables were examined.

Keywords: Gibbs thermodynamic microstates, hidden parameters and variables, inert free energy, Gibbs free energy, enthalpy, cooled down to the limit and quasi-equilibrium cooling down matter, latently coherent matter, Gibbs microstate, multiplicative component, gravithermodynamic bond, gravitational field, limit velocity of matter motion.

Introduction

Internal energy U of real gases and liquids depends on many pairs of their intensive (A_i) and extensive (a_i) thermodynamic parameters. However, it can also be shown as a sum of internal energy of hypothetic ideal gas (liquid) U_{id} and output of multiplication of resulting intensive ($A_\rho = TS/R_T = T^2 S/pV$) and extensive ($a_\rho \equiv R_T = pV/T$) thermodynamic parameters:

$$U = U_{id} + \sum_{i=2}^n A_i a_i = U_{id} + A_\rho a_\rho, \quad dU = T_{id} dS_{id} + A_\rho da_\rho - pdV = TdS - pdV,$$

where: $T_{id} = TR_T/R_{UT}$, $S_{id} = SR_{UT}/R_T$, $A_\rho a_\rho = T_{id} S_{id} = TS$. For gases: $a_i = R_{UT} B_i V^{1-i}$, B_i is virial coefficients that depend on both temperature and individual gas properties [1], while R_{UT} is universal gas constant and $R_T(r) = pV/T = \mathbf{const}(t)$ is spatial thermodynamic parameter of matter, that does not vary in space at conditions of quasi-equilibrium cooling down of matter (is the same on any radial distance r from the gravitational attraction center in the comoving to it frame of reference of spatial coordinates and time t). And exactly this invariability in space of $R_T(t)$ is responsible for the fact that properties of quasi-equilibrium cooling down real gases are close to properties of hypothetic ideal gas.

“Ideal” component U_{id} of internal energy is de facto identical to Helmholtz free energy F_T , while “ideal” component H_{Tid} of enthalpy is identical to the Gibbs free energy G :

$$H_{Tid} = H_T - a_\rho A_\rho = H_T - ST = G, \quad dH_{Tid} = T_{id} dS_{id} - a_\rho dA_\rho + V dp = -SdT + V dp = dG, \quad U_{id} = U - a_\rho A_\rho = U - ST = F_T, \\ dU_{id} = T_{id} dS_{id} - a_\rho dA_\rho - pdV = [TdS - (TS/R_T)dR_T] - [SdT + TdS - (TS/R_T)dR_T] - pdV = -SdT - pdV = dF_T.$$

This, of course, is caused by the absence of binding energy ($\sum_{i=2}^n A_i a_i = A_\rho a_\rho = 0$) in ideal gas and ideal liquid due to the absence of electromagnetic interaction of their molecules and atoms. Self-organization of hierarchically more complicated interactions and interconnections in matter is in the tendency of Helmholtz and Gibbs free energies to their minimum. Lower layers of matter,

loaded by its upper layers form the extended system. The energy of such extended system [1] that consists of the whole RGTD-bonded matter is indeed equivalent to enthalpy. Moreover, as it is shown further, parameter a_ρ (in contrast to A_ρ parameter) takes the same value in the whole space filled by quasi-equilibrium cooling down homogeneous matter $((\partial a_\rho / \partial r)_t = 0)$. And, therefore, Gibbs energy “behaves” as it is expected: it only changes in space along the radial coordinate r together with the gravitational potential. And when Gibbs energy changes in time together with the gravitational potential, it “behaves” like multiplicative component of enthalpy (like the energy of extended system).

All thermodynamic parameters and characteristics of matter are its internal properties and, in contrast to its mechanic characteristics, can be determined only in its intrinsic time. Gravity and velocity of matter motion have an influence only on the flow of intrinsic time of matter and, thus, on the formation of correspondent to it space-time continuum (STC). Their effect on the matter is purely gauge and, therefore, only leads to the formation of spatially inhomogeneous thermodynamic states of matter and to the emergence of correspondent to them thermodynamic processes.

Mutual dependencies of instantaneous values of main thermodynamic parameters and potentials of matter

Thermodynamic processes in matter confront the intranuclear evolutionary and gravitational processes in it. While in mechanics the main role is played by the inert free energy $H \equiv E = m_{in0} c^2 \Gamma = m_{00} c v_l \Gamma$ (equivalent to inertial mass $m_{in} = m_{00} v_l \Gamma / c$), in thermodynamics the main role is given to the total internal energy $U = W + U_{ad} = m_{gr0} c^2 \Gamma_m + U_{ad} = m_{00} c^3 \Gamma_m / v_l + U_{ad}$ of matter. Therefore, frequency of intranuclear interaction $f_G = q_N N_{RE} = \eta_m v_l / c \leq \eta_m$ corresponds to inversely proportional to it frequency of electromagnetic interaction of its molecules in the comoving FR: $f_l = q_M N_l = (v_{cm} / c) N_l = \psi_m c / v_l = \psi_{m0} c / v_{lc} \geq \psi_m$ ($f_{lcr} = f_{Gcr} = 1$). This frequency is changing together with the change of velocity of light $v_{cm} = c q_M \leq v_l$ in matter (that corresponds to radiation refractive index n_m at the wavelength of maximum of energy of thermal radiation) and with the change of internal scale factor $N_l = \delta l_{cr} / \delta l \leq 1$ of matter [2-4]. Here: $\chi_m = \chi_{m0} \Gamma_m = \Gamma_m / \Gamma_{mcr}$; $\psi_m = \psi_{m0} \Gamma_m = \chi_m / \eta_m = v_{lcr} \Gamma_m / c \Gamma_{mcr}$; $\psi_{m0} = \chi_{m0} / \eta_m = v_{lc/cr} / c = v_{lcr} / \Gamma_{mcr} c$ and $\eta_m = c / v_{lcr}$ are the constants of cooled down to the limit (χ_m, ψ_m) and quasi-equilibrium cooling down (χ_{m0}, ψ_{m0}) matter, which is not identical for different matters and for their various phase or aggregate states and not dependent both on strength of gravitational field and on matter thermodynamic parameters; v_l and v_{lcr} are maximum possible (limit) velocities of matter in any point on the phase boundary of the same matter and on the boundary of different matters correspondingly; $v_{lc} = v_l / \Gamma_m < v_l$ and $v_{lc/cr} = v_{lcr} / \Gamma_m$ are the limit velocity of quasi-equilibrium cooling down matter in the comoving with it the non-rigid FR (so not in the metric STC, but in the inseparable from matter its own physical STC, in which the radial motion of molecules of matter, which cooling down is absent and the time is counted by the clocks coming with them); $\Gamma_m = (1 - v_m^2 v_l^{-2})^{-1/2}$ and $\Gamma_{mcr} = 1 / \chi_{m0}$ are the expected Lorentz shrinkage of dimensions of matter (that moves in the process of quasi-equilibrium cooling down) in arbitrary point and on the phase boundary of the same matter or with another matter respectively; δl_{cr} is minimal possible distance of electromagnetic interaction between molecules of certain matter or its critical value; c is constant of the velocity of light.

In contrast to used in cosmology spatially inhomogeneous external scaling factor N_E , which is the cause of the curvature of matter intrinsic space, internal scaling factor N_l takes nonsimilar values for different matters and depends on thermodynamic state of matter. This factor characterizes the distinction between average statistic value of interaction distance δl in the atoms of concrete matter and the value of this distance δl_{cr} that corresponds to critical equilibrium

values of internal energy multiplicative component U_{cr} , Gibbs free energy G_{cr} , temperature T_{cr} , pressure p_{cr} . And if parameter $q_M = v_{cm}/c = 1/n_m < 1$ characterizes the difference of real velocity of electromagnetic interaction propagation in matter from the constant of velocity of light c , then N_I is responsible for compensation of the influence of increase of propagation velocity of electromagnetic wave on the frequency of electromagnetic interaction f_I of matter microobjects. If for gases and simplest liquids the dependencies of instantaneous values of their thermodynamic parameters and potentials on q_M and N_I allow to separate these variables, then instantaneous value of their Gibbs free energy (that corresponds to their instantaneous thermodynamic microstates) can be expressed via these two parameters and via their function R_T in the following way:

$$\tilde{G}(q_M, N_I, \tilde{R}_T) = \tilde{U}(q_M, N_I, \tilde{R}_T) - \tilde{S}(q_M, N_I, \tilde{R}_T) \tilde{T}(q_M, N_I, \tilde{R}_T) + \tilde{V}(q_M, N_I) \tilde{p}(q_M, N_I).$$

Methods of thermodynamics allow us to analyze equilibrium states of matter even when there is no analytic dependence of thermal energy of matter on its thermodynamic parameters. With the purpose of revealing of some features let us examine analytic representation of such dependency for gases and simple liquids. According to it the instantaneous values of main thermodynamic parameters and potentials can be represented in the following way:

$$\begin{aligned} \tilde{S} &= - \left(\frac{\partial \tilde{G}}{\partial \tilde{T}} \right)_{\tilde{p}} = - \left(\frac{\partial \tilde{F}_T}{\partial \tilde{T}} \right)_{\tilde{V}} = \frac{\beta_{ST} \tilde{R}_T}{\beta_{pV}} (\hat{S}), \quad \tilde{T} = \left(\frac{\partial \tilde{H}_T}{\partial \tilde{S}} \right)_{\tilde{p}} = \left(\frac{\partial \tilde{U}}{\partial \tilde{S}} \right)_{\tilde{V}} = \frac{\beta_{pV} U_{cr}}{\tilde{R}_T} (\hat{T}) = \frac{c \psi_m \beta_{pV} U_{cr}}{v_l \tilde{R}_T} = \frac{\beta_{pV} \tilde{U}_0}{\tilde{R}_T}, \\ \tilde{V} &= (\partial \tilde{H}_T / \partial \tilde{p})_{\tilde{S}} = (\partial \tilde{G} / \partial \tilde{p})_{\tilde{T}} = (U_{cr} / p_l) (\hat{V}), \quad \tilde{p} = - (\partial \tilde{U} / \partial \tilde{V})_{\tilde{S}} = - (\partial \tilde{F}_T / \partial \tilde{V})_{\tilde{T}} = \beta_{pV} p_l (\hat{p}), \\ \tilde{U} &= \tilde{U}_0 + \tilde{U}_{ad} = \frac{\tilde{R}_T \tilde{T}}{\beta_{pV}} + \int_{\tilde{R}_{T0}}^{\tilde{R}_T} \frac{\tilde{T} \tilde{S}}{\tilde{R}_T} d\tilde{R}_T = \frac{\tilde{p} \tilde{V}}{\beta_{pV}} + \beta_{ST} \int_{\tilde{R}_{T0}}^{\tilde{R}_T} (\hat{T})(\hat{S}) \frac{d\tilde{R}_T}{\tilde{R}_T} = U_{cr} \left[q_M N_I + \beta_{ST} \int_{\tilde{R}_{T0}}^{\tilde{R}_T} q_M N_I \ln(q_M^1 N_I) \frac{d\tilde{R}_T}{\tilde{R}_T} \right] = \\ &= \tilde{a}_\rho \tilde{T} / \beta_{pV} + \int_{\tilde{a}_{\rho 0}}^{\tilde{a}_\rho} \tilde{A}_\rho d\tilde{a}_\rho = U_{cr} \left[\left(\frac{p_l \tilde{V}}{U_{cr}} \right)^{-\beta_{pV}} \exp \left(\frac{\beta_{pV} \tilde{S}}{\tilde{R}_T} \right) + \beta_{pV} \int_{\tilde{R}_{T0}}^{\tilde{R}_T} \left(\frac{p_l \tilde{V}}{U_{cr}} \right)^{-\beta_{pV}} \exp \left(\frac{\beta_{pV} \tilde{S}}{\tilde{R}_T} \right) \frac{\tilde{S}}{\tilde{R}_T^2} d\tilde{R}_T \right] = \\ &= U_{cr} \left[\left(\frac{\tilde{p}}{\beta_{pV} p_l} \right)^{\frac{\beta_{pV}}{\beta_H}} \exp \left(\frac{\beta_{pV} \tilde{S}}{\beta_H \tilde{R}_T} \right) + \beta_{pV} \int_{\tilde{R}_{T0}}^{\tilde{R}_T} \left(\frac{\tilde{p}}{\beta_{pV} p_l} \right)^{\frac{\beta_{pV}}{\beta_H}} \exp \left(\frac{\beta_{pV} \tilde{S}}{\beta_H \tilde{R}_T} \right) \frac{\tilde{S}}{\tilde{R}_T^2} d\tilde{R}_T \right] = U_{cr} \left[(\hat{T}) + \beta_{ST} \int_{\tilde{R}_{T0}}^{\tilde{R}_T} (\hat{T})(\hat{S}) \frac{d\tilde{R}_T}{\tilde{R}_T} \right] = \\ &= \left\{ \tilde{R}_T \tilde{T} + \int_{\tilde{R}_{T0}}^{\tilde{R}_T} \left[\beta_H \ln \left(\frac{\tilde{R}_T \tilde{T}}{U_{cr} \beta_{pV}} \right) - \beta_{pV} \ln \left(\frac{\tilde{p}}{p_l \beta_{pV}} \right) \right] \tilde{T} d\tilde{R}_T \right\} \frac{1}{\beta_{pV}} = \frac{1}{\beta_{pV}} \left\{ \tilde{R}_T \tilde{T} + \int_{\tilde{R}_{T0}}^{\tilde{R}_T} \left[\ln \left(\frac{\tilde{R}_T \tilde{T}}{\beta_{pV} U_{cr}} \right) + \beta_{pV} \ln \left(\frac{p_l \tilde{V}}{U_{cr}} \right) \right] \tilde{T} d\tilde{R}_T \right\}, \\ \tilde{G} &= \tilde{H}_T - \tilde{S} \tilde{T} = U_{cr} \left[\beta_H (\hat{T}) - \beta_{ST} \int_{[(\hat{S})(\hat{T})/\tilde{R}_T]_0}^{(\hat{S})(\hat{T})/\tilde{R}_T} \tilde{R}_T d \left(\frac{(\hat{S})(\hat{T})}{\tilde{R}_T} \right) \right] = \tilde{G}_0 + \int_{\tilde{R}_{T0}}^{\tilde{R}_T} \frac{\tilde{S} \tilde{T}}{\tilde{R}_T} d\tilde{R}_T = \beta_H U_{cr} \left[1 - \ln(\hat{T}) + \frac{\beta_{pV}}{\beta_H} \ln(\hat{p}) \right] (\hat{T}) + \\ &+ \beta_H U_{cr} \int_{\tilde{R}_{T0}}^{\tilde{R}_T} \left[\ln(\hat{T}) - \frac{\beta_{pV}}{\beta_H} \ln(\hat{p}) \right] \frac{(\hat{T})}{\tilde{R}_T} d\tilde{R}_T = \tilde{H}_{T0} - \int_{\tilde{A}_{\rho 0}}^{\tilde{A}_\rho} \tilde{R}_T d\tilde{A}_\rho = \frac{\beta_H \tilde{a}_\rho \tilde{T}}{\beta_{pV}} - \int_{\tilde{A}_{\rho 0}}^{\tilde{A}_\rho} \tilde{a}_\rho d\tilde{A}_\rho = \frac{\beta_H \tilde{R}_T \tilde{T}}{\beta_{pV}} \left[1 - \ln \left(\frac{\tilde{R}_T \tilde{T}}{\beta_{pV} U_{cr}} \right) + \frac{\beta_{pV}}{\beta_H} \ln \left(\frac{\tilde{p}}{p_l} \right) \right] + \\ &+ \int_{\tilde{R}_{T0}}^{\tilde{R}_T} \left[\frac{\beta_H}{\beta_{pV}} \ln \left(\frac{\tilde{R}_T \tilde{T}}{\beta_{pV} U_{cr}} \right) - \ln \left(\frac{\tilde{p}}{\beta_{pV} p_l} \right) \right] \tilde{T} d\tilde{R}_T = c \psi_m \left\{ \frac{\beta_H}{v_l} \int_{\tilde{A}_{\rho 0}}^{\tilde{A}_\rho} \tilde{R}_T d \left(\frac{\beta_{ST}}{\tilde{R}_T v_l} \ln \left(\frac{c \psi_m}{v_l} \right) - (1-1) \ln n_m \right) \right\} = \\ &= \frac{c \psi_m U_{cr} \beta_{ST}}{v_l} \left\{ \left[\frac{\beta_H}{\beta_{ST}} - \ln \left(\frac{c \psi_m}{v_l} \right) + (1-1) \ln n_m \right] + v_l \int_{\tilde{R}_{T0}}^{\tilde{R}_T} \left[\ln \left(\frac{c \psi_m}{v_l} \right) - (1-1) \ln n_m \right] \frac{d\tilde{R}_T}{\tilde{R}_T v_l} \right\}, \end{aligned}$$

where: $\tilde{U}_0 = (\hat{T})U_{cr}$, $\tilde{H}_{T_0} = \beta_H \tilde{U}_0$, $\tilde{G}_0 = \beta_G \tilde{U}_0$, \tilde{F}_{T_0} are multiplicatively dependent on $q_M = 1/n_m$ and N_I components of instantaneous values of internal energy, enthalpy, Gibbs free energy and Helmholtz free energy of instantaneous Gibbs microstate of matter correspondingly;

$$\tilde{U}_{ad} = \sum_{i=2}^n \int_{\tilde{a}_{i0}}^{\tilde{a}_i} \tilde{A}_i d\tilde{a}_i = \int_{\tilde{a}_{\rho 0}}^{\tilde{a}_{\rho}} \tilde{A}_{\rho} d\tilde{a}_{\rho} = \int_{\tilde{R}_{T_0}}^{\tilde{R}_T} (\tilde{T}\tilde{S}/\tilde{R}_T) d\tilde{R}_T > 0$$

is instantaneous value of realized via negative

feedback partial additive compensation of multiplicative representation of thermodynamic potentials of microstate of matter (a multiplicative decrease in its free energies over time);

$$\tilde{A}_{\rho} = \tilde{T}\tilde{S}/\tilde{R}_T, \tilde{a}_{\rho} \equiv \tilde{R}_T = \tilde{p}\tilde{V}/\tilde{T}; (\hat{V}) = q_M^{-1/k} N_I^{-m} = q_M^{m-1/k} f_I^{-m} = f_I^{-1/k} N_I^{1/k-m} = (v_l/c\psi_m)^{1/\beta_{pV}} \exp(S/R_T),$$

$$(\hat{p}) = q_M^{1+1/k} N_I^{1+m} = q_M^{1/k-m} f_I^{1+m} = f_I^{1+1/k} N_I^{m-1/k} = (v_l/c\psi_m)^{-\beta_H/\beta_{pV}} \exp(-S/R_T),$$

$(\hat{S}) = \ln(q_M^1 N_I) = \ln(f_I^1 N_I^{1-1})$, $(\hat{T}) = (\hat{p})(\hat{V}) = q_M N_I = f_I = \chi_m / f_G = \psi_m c / v_{cv} \equiv \psi_m c / v_l = \psi_m b^{-1/2}$ are normalized values of thermodynamic parameters (entropy, temperature, molar volume and pressure) of Gibbs microstates of matter;

$$\beta_{ST} = (km-1)/(k\lfloor m-1 \rfloor) > 0, \beta_{pV} = k(1-1)/(k\lfloor m-1 \rfloor) > 0, \beta_H = H_{T_0}/U_0 = 1 + \beta_{pV} = [k(\lfloor m+1 \rfloor - 1)] / (k\lfloor m-1 \rfloor),$$

$$\beta_G = \frac{\tilde{G}_0}{\tilde{U}_0} = 1 + \beta_{pV} - \beta_{ST} \ln(q_M^1 N_I) = \beta_H - \frac{1(km-1)}{k\lfloor m-1 \rfloor} \ln q_M - \frac{km-1}{k\lfloor m-1 \rfloor} \ln N_I = \frac{k(\lfloor m+1 \rfloor - 1) - 1(km-1)}{k\lfloor m-1 \rfloor} \ln f_I + \frac{(km-1)(1-1)}{k\lfloor m-1 \rfloor} \ln N_I,$$

$$\beta_{GR} = \frac{\tilde{G}}{\tilde{U}_0} = 1 + \beta_{pV} - \frac{\beta_{ST}}{(\hat{T})} \int_{\tilde{A}_{\rho 0}}^{\tilde{A}_{\rho}} \tilde{R}_T d\tilde{A}_{\rho} = \frac{k(\lfloor m+1 \rfloor - 1) - 1}{k\lfloor m-1 \rfloor} - \frac{km-1}{(k\lfloor m-1 \rfloor) q_M N_I} \int_{[(\hat{S})/(\hat{T})/\tilde{R}_T]_0}^{(\hat{S})/(\hat{T})/\tilde{R}_T} \tilde{R}_T d \left[\frac{q_M N_I \ln(q_M^1 N_I)}{\tilde{R}_T} \right];$$

$p_l = n p_{cr}$, while: n is the hidden variable that is the indicator of the magnitudes of instantaneous microfluctuations of values of pressure and molar volume when $\tilde{p}\tilde{V} = \mathbf{const}$ and during not absolutely rigid retention of occupied by gas constant volume;

k, \lfloor , m are the hidden variables that are indicators of the influence of parameters q_M and N_I on the parameters of thermodynamic microstates of latently coherent matter.

Variables k, \lfloor , m and n characterize instantaneous collective microstates of the whole gravithermodynamically bonded matter and similarly to the wave functions of quantum mechanics can take with certain probability any arbitrary instantaneous values. The probability that Gibbs microstate of matter have instantaneous energy, the corresponding certain composition of values of these variables, obviously, is represented by canonic Gibbs distribution. The concrete mathematical expectations $\tilde{k}(R_T)$, $\tilde{\lfloor}(R_T)$, $\tilde{m}(R_T)$, $\tilde{n}(R_T)$ of those variables (that depend on the parameter R_T) correspond to parameters of a thermodynamic macrostate of matter.

Normalized values of thermodynamic parameters of instantaneous microstates of matter are mutually related via the following dependencies:

$$(\hat{S}) = 1 \ln q_M + \ln N_I = 1 \ln \left(\frac{c\psi_m}{v_l} \right) - (1-1) \ln \left(\frac{\sigma_m}{N_{RE}} \right) = \frac{\beta_H}{\beta_{ST}} \ln(\hat{T}) - \frac{\beta_{pV}}{\beta_{ST}} \ln(\hat{p}) = \frac{\ln(\hat{T})}{\beta_{ST}} + \frac{\beta_{pV}}{\beta_{ST}} \ln(\hat{V}) = \frac{\beta_H}{\beta_{ST}} \ln(\hat{V}) + \frac{\ln(\hat{p})}{\beta_{ST}},$$

$$\ln(\hat{T}) = \ln q_M + \ln N_I = \ln \left(\frac{c\psi_m}{v_l} \right) = \frac{\beta_{ST}}{\beta_H} (\hat{S}) + \frac{\beta_{pV}}{\beta_H} \ln(\hat{p}) = \beta_{ST} (\hat{S}) - \beta_{pV} \ln(\hat{V}) = \ln(\hat{p}) + \ln(\hat{V}),$$

$$\ln(\hat{V}) = -\frac{\ln q_M}{k} - m \ln N_I = -m \ln \left(\frac{c\psi_m}{v_l} \right) + \frac{1-km}{k} \ln n_m = \frac{\beta_{ST}}{\beta_H} (\hat{S}) - \frac{\ln(\hat{p})}{\beta_H} = \frac{\beta_{ST}}{\beta_{pV}} (\hat{S}) - \frac{\ln(\hat{T})}{\beta_{pV}} = \ln(\hat{T}) - \ln(\hat{p}),$$

$$\ln(\hat{p}) = \frac{k+1}{k} \ln q_M + (m+1) \ln N_I = (m+1) \ln \left(\frac{c\psi_m}{v_l} \right) + \frac{km-1}{k} \ln n_m = (\hat{S}) \beta_{ST} - \beta_H \ln(\hat{V}) = -\frac{\beta_{ST}}{\beta_{pV}} (\hat{S}) + \frac{\beta_H}{\beta_{pV}} \ln(\hat{T}) = \ln(\hat{T}) - \ln(\hat{V}).$$

As it was expected, all instantaneous thermodynamic potentials reach their minimum independently both on the values of variables k, \lfloor , m, n and on the value of spatial gas-related

parameter \check{R}_T : $(\partial\check{U}/\partial\check{R}_T)_{\check{S},\check{V}}=0$, $(\partial\check{H}_T/\partial\check{R}_T)_{\check{S},\check{p}}=0$, $(\partial\check{F}_T/\partial\check{R}_T)_{\check{T},\check{V}}=0$, $(\partial\check{G}/\partial\check{R}_T)_{\check{T},\check{p}}=0$. And, moreover, the change in space of available thermodynamic parameters of cooling down matter is inevitably accompanied by the change of its hidden thermodynamic parameters Γ_m and v_l :

$$\left(\frac{\partial U}{\partial \check{r}}\right)_t = T \left(\frac{\partial S}{\partial \check{r}}\right)_t - p \left(\frac{\partial V}{\partial \check{r}}\right)_t = U_0 \left[\left(\frac{\partial \ln \Gamma_m}{\partial \check{r}}\right)_t - \left(\frac{\partial \ln v_l}{\partial \check{r}}\right)_t \right], \quad \left(\frac{\partial H_T}{\partial \check{r}}\right)_t = T \left(\frac{\partial S}{\partial \check{r}}\right)_t + V \left(\frac{\partial p}{\partial \check{r}}\right)_t = H_{T0} \left[\left(\frac{\partial \ln \Gamma_m}{\partial \check{r}}\right)_t - \left(\frac{\partial \ln v_l}{\partial \check{r}}\right)_t \right],$$

where: $\partial \check{r}$ is the increment of metric radial distance.

And the bigger the distance from matter to the gravitational attraction center the smaller is its internal energy. That is why in contrast to inert free energy (which is the greater the greater the distance from the substance to the gravitational attraction center) the thermal energy behaves like a negative mass. And this is confirmed by numerous investigations of the influence of heating of matter on its weight [5-6].

Precisely the condition of spatial homogeneity of hierarchic complexity of RGTD-bonded matter $R_T = \mathbf{const}(r)$ determines the spatial distribution of the set of main thermodynamic parameters of this quasi-equilibrium cooling down matter. Since parameter:

$$R_T = TS/A_\rho = U_{cr} \check{\beta}_{ST} q_M N_I \ln(q_M^I N_I) / A_\rho = U_{cr} \check{\beta}_{ST} c \psi_m [\ln \psi_m - \ln(v_l/c) + (\check{l} - 1) \ln(v_{cm}/c)] / A_\rho v_l \neq R_{T0}$$

expressed not only via constants (including also $A_\rho = \mathbf{const}(t)$ which characterizes the quasi-equilibrium of the process of cooling down of matter throughout the whole time), but also via velocity of the light in matter v_{cm} , limit velocity of motion v_l and Lorentz shrinkage of dimensions of the matter that moves in the process of quasi-equilibriumly cooling down $\Gamma_m \neq \mathbf{const}(r)$ ($\psi_m = \psi_{m0} \Gamma_m \neq \mathbf{const}(r)$), then only via them we can in temporal form (via A_ρ) or in spatial form (via $a_\rho \equiv R_T$) express instantaneous values of all main thermodynamic parameters and potentials of RGTD-bonded matter:

$$\check{T} = \frac{\check{A}_\rho \beta_{pV}}{\beta_{ST} (\ln q_M + \ln N_I)} = \frac{\check{A}_\rho \beta_{pV}}{\beta_{ST} [\ln \psi_{m0} - \ln(v_l/c) + (\check{l} - 1) \ln(v_{cm}/c)]} = \frac{U_{cr} \beta_{pV} q_M N_I}{\check{R}_T} = \frac{U_{cr} \beta_{pV} c \psi_{m0}}{\check{R}_T v_{lc}} = \frac{\check{p} \check{V}}{\check{R}_T} =$$

$$= \frac{U_{cr} \beta_{pV}}{\check{R}_T} \left[\frac{U_{cr}}{p_l \check{V}} \exp\left(\frac{\check{S}}{\check{R}_T}\right) \right]^{\beta_{pV}} = \beta_{pV} \check{A}_\rho \left[\ln\left(\frac{\check{p}}{p_l \beta_{pV}}\right) + (1 + \beta_{pV}) \ln\left(\frac{p_l \check{V}}{U_{cr}}\right) \right]^{-1} = \frac{U_{cr} \beta_{pV}}{\check{R}_T} \left[\frac{\check{p}}{p_l \beta_{pV}} \exp\left(\frac{\check{S}}{\check{R}_T}\right) \right]^{\beta_{pV} / \beta_H},$$

$$\check{S} = \frac{U_{cr} \beta_{ST}^2 q_M N_I (\ln q_M + \ln N_I)^2}{\beta_{pV} \check{A}_\rho} = \frac{\beta_{ST} \check{R}_T (\ln q_M + \ln N_I)}{\beta_{pV}} = \frac{U_{cr} c \psi_{m0} \beta_{ST}^2 [\ln \psi_{m0} - \ln(v_l/c) + (\check{l} - 1) \ln(v_{cm}/c)]^2}{\beta_{pV} \check{A}_\rho v_{lc}} =$$

$$= (\beta_{ST} \check{R}_T / \beta_{pV}) [\ln \psi_{m0} + \ln \Gamma_m - \ln(v_l/c) + (\check{l} - 1) \ln(v_{cm}/c)] = (\beta_{pV}^{-2} \check{p} \check{V} / \check{A}_\rho) [\ln(\check{p} / p_l \beta_{pV}) + \beta_H \ln(\check{V} p_l / U_{cr})]^2 =$$

$$= \frac{U_{cr} \beta_{pV} \check{A}_\rho}{\check{T}^2} \left[\frac{\check{p}}{p_l \beta_{pV}} \exp\left(\frac{\check{A}_\rho}{\check{T}}\right) \right]^{\beta_{pV} / \beta_H} = \frac{U_{cr} \beta_{pV} \check{A}_\rho}{\check{T}^2} \left[\frac{U_{cr}}{p_l \check{V}} \exp\left(\frac{\check{A}_\rho}{\check{T}}\right) \right]^{\beta_{pV}},$$

$$\check{p} = p_l \beta_{pV} q_M^{1+1/k} N_I^{1+m} = p_l \beta_{pV} \left(\frac{c \psi_{m0} \Gamma_m}{v_l} \right)^{1+m} \left(\frac{c}{v_{cm}} \right)^{m-1/k} = \frac{\check{R}_T \check{T}}{\check{V}} = p_l \beta_{pV} \left(\frac{U_{cr}}{p_l \check{V}} \right)^{1+\beta_{pV}} \exp\left(\frac{\beta_{pV} \check{A}_\rho}{\check{T}}\right) =$$

$$= p_l \beta_{pV} \left(\frac{\check{R}_T \check{T}}{U_{cr} \beta_{pV}} \right)^{1+1/\beta_{pV}} \exp\left(\frac{\check{S}}{\check{R}_T}\right) = p_l \beta_{pV} \left(\frac{\check{S} \check{T}^2}{U_{cr} \beta_{pV} \check{A}_\rho} \right)^{1+1/\beta_{pV}} \exp\left(\frac{\check{A}_\rho}{\check{T}}\right) = p_l \beta_{pV} \left(\frac{U_{cr}}{p_l \check{V}} \right)^{1+\beta_{pV}} \exp\left(\frac{\beta_{pV} \check{S}}{\check{R}_T}\right),$$

$$\check{V} = \frac{U_{cr}}{p_l q_M^{1/k} N_I^m} = \frac{U_{cr}}{p_l} \left(\frac{v_{lc}}{c \psi_{m0}} \right)^m \left(\frac{v_{cm}}{c} \right)^{m-1/k} = \frac{U_{cr}}{p_l} \left[\left(\frac{p_l \beta_{pV}}{\check{p}} \right) \exp\left(\frac{\beta_{pV} \check{A}_\rho}{\check{T}}\right) \right]^{1+\beta_{pV}} = \frac{U_{cr}}{p_l} \left(\frac{U_{cr} \beta_{pV}}{\check{R}_T \check{T}} \right)^{1+\beta_{pV}} \exp\left(\frac{\check{S}}{\check{R}_T}\right) =$$

$$\begin{aligned}
 &= \frac{\tilde{R}_T \tilde{T}}{\tilde{p}} = \frac{U_{cr}}{p_l} \left(\frac{U_{cr} \beta_{pV} \tilde{A}_\rho}{\tilde{S} \tilde{T}^2} \right)^{\beta_{pV}} \exp\left(\frac{\tilde{A}_\rho}{\tilde{T}}\right) = \frac{U_{cr}}{p_l} \left[\left(\frac{p_l \beta_{pV}}{\tilde{p}} \right) \exp\left(\frac{\beta_{pV} \tilde{S}}{\tilde{R}_T}\right) \right]^{\frac{1}{1+\beta_{pV}}}, \\
 \tilde{U} = \tilde{U}_0 + \tilde{U}_{ad} &= U_{cr} q_M N_I + \int_{\tilde{R}_{T0}}^{\tilde{R}_T} \tilde{S} \tilde{T} \frac{d\tilde{R}_T}{\tilde{R}_T} = \tilde{U}_0 + \tilde{S} \tilde{T} - \int_{\tilde{A}_{\rho 0}}^{\tilde{A}_\rho} \tilde{S} \tilde{T} \frac{d\tilde{A}_\rho}{\tilde{A}_\rho} = U_{cr} [1 + \beta_{ST} \ln(q_M^1 N_I)] q_M N_I - \int_{\tilde{A}_{\rho 0}}^{\tilde{A}_\rho} \tilde{R}_T d\tilde{A}_\rho = \\
 &= \frac{U_{cr} \psi_{m0} c}{v_{lc}} + \int_{\tilde{R}_{T0}}^{\tilde{R}_T} \tilde{S} \tilde{T} \frac{d\tilde{R}_T}{\tilde{R}_T} = \tilde{S} \tilde{T} \left(1 + \frac{\tilde{T}}{\beta_{pV} \tilde{A}_\rho} \right) - \int_{\tilde{A}_{\rho 0}}^{\tilde{A}_\rho} \tilde{S} \tilde{T} \frac{d\tilde{A}_\rho}{\tilde{A}_\rho} = U_{cr} \left(1 + \frac{\beta_{pV} \tilde{A}_\rho}{\tilde{T}} \right) \left(\frac{\tilde{p}}{p_l \beta_{pV}} \exp\left(\frac{\tilde{A}_\rho}{\tilde{T}}\right) \right)^{\beta_{pV}/\beta_H} - \int_{\tilde{A}_{\rho 0}}^{\tilde{A}_\rho} \tilde{R}_T d\tilde{A}_\rho = \\
 &= U_{cr} \left(1 + \frac{\beta_{pV} \tilde{A}_\rho}{\tilde{T}} \right) \left[\frac{U_{cr}}{p_l \tilde{V}} \exp\left(\frac{\tilde{A}_\rho}{\tilde{T}}\right) \right]^{\beta_{pV}} - \int_{\tilde{A}_{\rho 0}}^{\tilde{A}_\rho} \tilde{R}_T d\tilde{A}_\rho = \frac{\tilde{p} \tilde{V}}{\beta_{pV}} \left[1 + \ln\left(\frac{\tilde{p}}{p_l \beta_{pV}}\right) + (1 + \beta_{pV}) \ln\left(\frac{p_l \tilde{V}}{U_{cr}}\right) \right] - \int_{\tilde{A}_{\rho 0}}^{\tilde{A}_\rho} \tilde{R}_T d\tilde{A}_\rho, \\
 \tilde{G} = \tilde{H}_{T0} - \tilde{U}_{ad}^* &= \frac{U_{cr} \beta_H \psi_{m0} c}{v_{lc}} - \int_{\tilde{A}_{\rho 0}}^{\tilde{A}_\rho} \tilde{R}_T d\tilde{A}_\rho = \frac{\beta_H \tilde{S} \tilde{T}^2}{\beta_{pV} \tilde{A}_\rho} - \int_{\tilde{A}_{\rho 0}}^{\tilde{A}_\rho} \tilde{S} \tilde{T} \frac{d\tilde{A}_\rho}{\tilde{A}_\rho} = \frac{\beta_H \tilde{p} \tilde{V}}{\beta_{pV}} - \int_{\tilde{A}_{\rho 0}}^{\tilde{A}_\rho} \frac{\tilde{p} \tilde{V}}{\beta_{pV}} \left[\ln \frac{\tilde{p}}{p_l \beta_{pV}} + \beta_H \ln \frac{p_l \tilde{V}}{U_{cr}} \right] \frac{d\tilde{A}_\rho}{\tilde{A}_\rho} = \\
 &= U_{cr} \left\{ (1 + \beta_{pV}) \left[\frac{\tilde{p}}{p_l \beta_{pV}} \exp\left(\frac{\tilde{A}_\rho}{\tilde{T}}\right) \right]^{\beta_{pV}/\beta_H} - \int_{\tilde{A}_{\rho 0}}^{\tilde{A}_\rho} \frac{\beta_{pV}}{\tilde{T}} \left[\frac{\tilde{p}}{p_l \beta_{pV}} \exp\left(\frac{\tilde{A}_\rho}{\tilde{T}}\right) \right]^{\beta_{pV}/\beta_H} d\tilde{A}_\rho \right\} = \\
 &= U_{cr} \left\{ (1 + \beta_{pV}) \left[\frac{U_{cr}}{p_l \tilde{V}} \exp\left(\frac{\tilde{A}_\rho}{\tilde{T}}\right) \right]^{\beta_{pV}} - \int_{\tilde{A}_{\rho 0}}^{\tilde{A}_\rho} \frac{\beta_{pV}}{\tilde{T}} \left[\frac{U_{cr}}{p_l \tilde{V}} \exp\left(\frac{\tilde{A}_\rho}{\tilde{T}}\right) \right]^{\beta_{pV}} d\tilde{A}_\rho \right\},
 \end{aligned}$$

where: $(\partial \tilde{U} / \partial \tilde{A}_\rho)_{\tilde{S}, \tilde{V}} = 0$, $(\partial \tilde{H}_T / \partial \tilde{A}_\rho)_{\tilde{S}, \tilde{p}} = 0$, $(\partial \tilde{F}_T / \partial \tilde{A}_\rho)_{\tilde{T}, \tilde{V}} = 0$, $(\partial \tilde{G} / \partial \tilde{A}_\rho)_{\tilde{T}, \tilde{p}} = 0$; $v_{lc} = \Gamma_m v_l$ is the limit velocity of quasi-equilibrium cooling down matter in comoving with it FR (in its own space-time continuum (STC), in which the radial motion of molecules of cooling down matter is absent);

$\tilde{U}_{ad}^* = \int_{\tilde{A}_{\rho 0}}^{\tilde{A}_\rho} \tilde{R}_T d\tilde{A}_\rho = \int_{\tilde{A}_{\rho 0}}^{\tilde{A}_\rho} (\tilde{S} \tilde{T} / \tilde{A}_\rho) d\tilde{A}_\rho \geq 0$ is instantaneous value of partial additive compensation of

multiplicative representation of thermodynamic potentials of matter microstate (multiplicative increase of bound energy as we approach the gravitational attraction center); \tilde{G} is the instantaneous value of Gibbs energy G (that is similar to the Lagrangian, since it constantly tends to its minimum too). As we can see, due to $A_\rho(r) = \mathbf{const}(t)$ when homogeneous matter is quasi-equilibrium cooling down the gravitational changes in time of its Gibbs free energy and Helmholtz free energy take place similarly to the changes in space of multiplicative component of internal energy U_0 and enthalpy H_{T0} correspondingly. Precisely, if when $\psi_{m0}^* = \psi_{m0} c / v_{lc}$:

$$\left(\frac{\partial U}{\partial \tilde{t}} \right)_r = -(U_0 + U_{ad}^*) \left\{ 1 + \frac{\tilde{\beta}_{ST}}{1 + \tilde{\beta}_{ST} [\ln \psi_{m0}^* + (\tilde{l} - 1) \ln n_m]} \right\} \left[\left(\frac{\partial \ln v_l}{\partial \tilde{t}} \right)_r - \left(\frac{\partial \Gamma_m}{\partial \tilde{t}} \right)_r \right] + \frac{(U_0 + U_{ad}^*) \tilde{\beta}_{ST} (\tilde{l} - 1)}{1 + \tilde{\beta}_{ST} [\ln \psi_{m0}^* + (\tilde{l} - 1) \ln n_m]} \left(\frac{\partial \ln n_m}{\partial \tilde{t}} \right)_r,$$

then: $(\partial F_T / \partial \tilde{t})_r = -S(\partial T / \partial \tilde{t})_r - p(\partial V / \partial \tilde{t})_r = -U_0 (\partial \ln v_{lc} / \partial \tilde{t})_r = -U_0 [(\partial \ln \Gamma_m / \partial \tilde{t})_r - (\partial \ln v_l / \partial \tilde{t})_r]$,

$$(\partial G / \partial \tilde{t})_r = -S(\partial T / \partial \tilde{t})_r + V(\partial p / \partial \tilde{t})_r = -H_{T0} (\partial \ln v_{lc} / \partial \tilde{t})_r = H_{T0} [(\partial \ln \Gamma_m / \partial \tilde{t})_r - (\partial \ln v_l / \partial \tilde{t})_r],$$

where: $\partial \tilde{t}$ is the increment of metric time of cooling down matter in a comoving with it FR.

In the process of free fall of matter in gravitational field the Helmholtz and Gibbs thermodynamic free energies, as well as the Hamiltonian of inert free energy of matter, are conserved not only due to the presence of weightlessness in its FR ($v_{lc} = v_l / \Gamma_m = \mathbf{const}(t)$), but also due to the total compensation of the influence of gravitation on its thermodynamic state by the motion. However it is possible only in hypothetical absolutely empty space. But when there is a

resistance to motion these energies will be gradually increasing due to the matter cannot reach the required for their conservation value Γ_m and thus also due to accommodation of the matter of falling body to the new thermodynamic state of matter of the environment.

Before the appearance of spatial inhomogeneity of limit velocity of matter v_l the only thing that could interfere its distancing from the future gravitational attraction center (due to tending of its Gibbs thermodynamic energy to its minimum) was the electromagnetic interaction of its molecules. That is why the hypothetic ideal gas and ideal liquid in principle cannot create their gravitational field. As we see, here we have a dependency of spatial distribution of intrinsic values of these thermodynamic parameters and potentials (not the dependency of spatial distribution of other their values observed by other clocks and by other length standards) on v_l (and, so, also on Γ_m and v_l). It would be non-logical if Γ_m and v_l would not influence on spatial distribution of the set of intrinsic values of main thermodynamic parameters of matter. So this does not contradict to invariance of thermodynamic parameters and potentials of matter relatively to the space-time transformations [Danylchenko, 2008: 19]. On the contrary, it only confirms the fact that limit velocity of matter motion v_l , as well as Γ_m , is the internal hidden RGTD-parameter of matter and not the non-dependent on certain RGTD-state of matter external gravitational parameter.

Conclusion

The gravitational reduction of molar volume of matter when approaching the gravitational attraction center is unobservable directly in intrinsic FRs of matter. However, we still can say about its presence in Euclidean space of CFREU due to the presence of gravitational curvature of intrinsic space of matter. And we also can indirectly say about the presence of evolutionary self-contraction of matter due to the presence of the process of Universe expansion in FR of people's world. In the equations, which combine the instantaneous values of main thermodynamic parameters and potentials (that are characteristic to Gibbs thermodynamic microstates), the maximum possible (limit) velocity of matter transfer and Lorentz shrinkage of dimensions of matter as well as four wave functions and derivatives from them, which can take with certain probability any arbitrary instantaneous values, can be used as thermodynamic hidden parameters and variables.

Gases and liquids can gradually (evolutionally) quasi-equilibrium cool down with the self-creation of stable gravitational fields due to electromagnetic interaction of their molecules. In these fields all values of extensive parameter $\tilde{a}_\rho \equiv \tilde{R}_T = \tilde{p}\tilde{V}/\tilde{T}$ is the same in the whole space at the same time and correspondent to it intensive parameter $A_\rho = TS/R_T = T^2S/pV$ is conserved in time.

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