S- LINE AND ENTROPY IN TECHNOLOGY, ECONOMICS AND PHYSICO-CHEMICAL STUDIES

G. A. Korablev,[a]* G. E. Zaikov,[c] V. I. Kodolov,[b] Yu. G. Vasiliev,[a] P. L. Maksimov,[a] N. G. Petrova[d] and P. B. Akmarov[a]

The concept of the entropy of spatial-energy interactions is used similarly to the ideas of thermodynamics on the static entropy. In this research we are trying to apply the concept of entropy to assess the degree of spatial-energy interactions using their graphic dependence and a nomogram to assess the entropy of different processes is obtained. The variability of entropy demonstrations is discussed, in biochemical processes, economics and engineering systems as well.

* Corresponding Authors
    E-Mail: korablevga@mail.ru
[a] Department of Physics, Izhevsk State Agricultural Academy, Russia.
[b] Department of Chemistry and Chemical Engineering of Kalashnikov Izhevsk State Technical University, 426069, Izhevsk, Studencheskaya 7, Russia.
[c] Institute of Biochemical Physics, Russian Academy of Science, Russia.
[d] Agency of Informatization and Communication, Udmurt Republic

Introduction

In statistical thermodynamics, the entropy of the closed and equilibrious system equals the logarithm of the probability of its definite macrostate (Eqn.1).

$$S = k \ln W \qquad (1)$$

where

W is the number of available states of the system or degree of the degradation of microstates and

k is Boltzmann's constant.

or

$$W = e^{s/k} \qquad (2)$$

These correlations are general assertions of macroscopic character, they do not contain any references to the structure elements of the systems considered and they are completely independent of microscopic models.[1] Therefore the application and consideration of these laws can result in a large number of consequences.

At the same time, the main characteristic of the process is the thermodynamic probability W. In actual processes of the isolated-system type, the entropy growth is inevitable i.e., disorder and chaos increase in the system the quantity of internal energy goes down. The thermodynamic probability equals the number of microstates corresponding to the given macrostate. Since the degree of system degradation is not connected with the physical features of the systems, the entropy statistic concept can also have other applications and demonstrations, apart from statistical thermodynamics.

It is clear that in two systems, completely different in their physical content, the entropy can be the same if their number of possible microstates corresponding to one macroparameter (whatever parameter it is) coincides. Therefore the idea of entropy can be used in various fields. The increasing self-organization of human society leads to the increase in entropy and disorder in the environment that is demonstrated, in particular, by a large number of disposal sites all over the earth.[2]

In this article, we are trying to apply the concept of entropy to assess the degree of spatial-energy interactions using their graphic dependence, and in other fields.

Entropic nomogram of the degree of spatial-energy interactions

The idea of spatial-energy parameter (*P*-parameter), which is the complex characteristic of the most important atomic values responsible for interatomic interactions and having the direct bond with the atom electron density, was introduced based on the modified Lagrangian equation for the relative motion of two interacting material points.[3] The value of the relative difference of *P*-parameters of interacting atoms-components – the structural interaction coefficient α is used as the main numerical characteristic of structural interactions in condensed media (Eqn. 3).

$$\alpha = \frac{P_1 - P_2}{(P_1 + P_2)/2} * 100 \qquad (3)$$

Applying the reliable experimental data, we obtained the nomogram of structural interaction degree dependence (ρ) on coefficient α, for a wide range of structures (Figure 1).
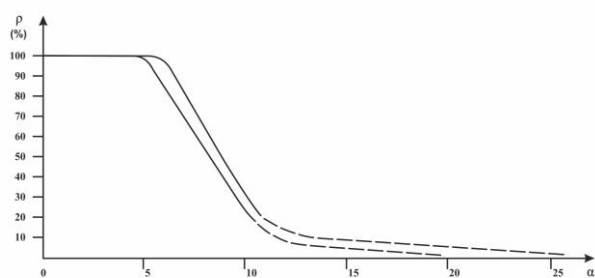
Figure 1. Nomogram of dependence of degree of structural interactions (ρ) on coefficient α.

This approach raises a possibility of evaluating the degree and direction of the structural interactions of phase formation, isomorphism and solubility processes in multiple systems, including molecular ones. Such nomogram can be demonstrated[3] as a logarithmic dependence also (Eqn. 4).

$$\alpha = \beta \left(\ln \rho \right)^{-1} \qquad (4)$$

where coefficient β is the constant value for the given class of structures. β can structurally change mainly within $\pm$ 5% from the average value. Thus coefficient α is inversely proportional to the logarithm of the degree of structural interactions and therefore can be characterized as the entropy of spatial-energy interactions of atomic-molecular structures.

Actually the more is ρ, higher is the probability of the formation of stable ordered structures (e.g. the formation of solid solutions), i.e. the less is the process entropy and also the less is coefficient α. The equation (4) does not have the complete analogy with Boltzmann's equation (1) as in this case not the absolute but only relative values of the corresponding characteristics of the interacting structures are compared which can be expressed in percent. This refers not only to coefficient α but also to the comparative evaluation of structural interaction degree (ρ), for example, the percent of atom content of the given element in the solid solution relatively to the total number of atoms. Therefore in equation (4) coefficient $k = 1$. Thus, the relative difference of spatial-energy parameters of the interacting structures can be a quantitative characteristic of the interaction entropy, i.e. $\alpha \equiv S$.

Entropic nomogram of surface-diffusive processes

As an example, let us consider the process of carbonization and formation of nanostructures during the interactions in polyvinyl alcohol gels and copper oxides or chlorides. At the first stage, small clusters of inorganic phase are formed surrounded by carbon containing phase. In this period, the main character of atomic-molecular interactions needs to be assessed via the relative difference of *P*-parameters calculated by involving the radii of copper ions

and covalent radii of carbon atoms. In the next main carbonization period the metal phase is being formed on the surface of the polymeric structures. From this point, the binary matrix of the nanosystem, C $\rightarrow$ Cu, is being formed.
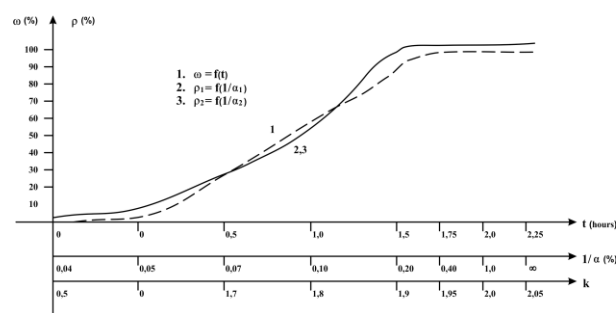
Figure 2. Dependence of the carbonation rate coefficient α in the formation of nanosystems C$\rightarrow$Cu

The values of the degree of structural interactions, calculated from coefficient α by Eqn. 5, are given in Figure 2 (curve 2). Here, the graphical dependence of the degree of nanofilm formation (ω) on the process time is presented by the data obtained earlier[4] (curve 1) and previously obtained nomogram from Eqn. 6 is presented in curve 3.

$$\rho_1 = f\left(\frac{1}{\alpha_1} \right) \qquad (5)$$

$$\rho_2 = f\left(\frac{1}{\alpha_2} \right) \qquad (6)$$

The analysis of all the observed graphical dependencies demonstrates the practically complete graphical coincidence of all the three graphs with slight deviations in the beginning and end of the process. Thus, the carbonization rate, as well as the functions of many other physical-chemical structural interactions, can be accessed from the values of the calculated coefficient α and entropic nomogram.

Entropy in the kinetics of physiological processes

The formation of ferment-substrate complex is the necessary stage of fermentative catalysis. One or more than one substrate molecules can join the ferment molecule.[5] For ferments with stoichiometric coefficient not equal one, the type of graphical dependence of the reaction product performance rate (μ) depending on the substrate concentration (*c*) has a sigmoid character with the specific bending point (Figure 3).[6] From Figure 3 it is apparent that this curve in general is similar to the character of the entropic nomogram in Figure 1. The graph of the dependence of electron transport rate in biostructures on the diffusion time scale of ions is similar.[6]

In the procedure of assessing fermentative interactions, it was assumed that the effective number of interacting molecules is more than one. In the methodology of ρ-parameter, a ferment has a limited isomorphic similarity with substrate molecules and does not form a stable compound with them, but, at the same time, some limited reconstruction of chemical bonds takes place, which makes it possible to obtain the final product.
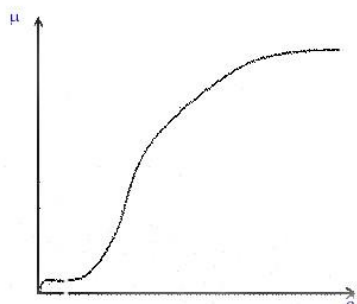
Figure 3. Dependence of the fermentation reaction rate (μ) on the substrate concentration (*c*)

Dependence of biophysical criteria on their frequency characteristics

The passing of alternating current through live tissues is characterized by the dispersive curve of electrical conductivity, which is directly dependent on the total resistance of tissue (*z*-impedance) on the alternating current frequency logarithm (log ω). Normally, such curve, on which the impedance is plotted on the coordinate axis, and log ω on the abscissa axis, formally, completely corresponds to the entropic nomogram (Figure 1). The fluctuations of biomembrane conductivity (conditioned by random processes) have the form of Lorentz curve.[5] In this graph, the fluctuation spectral density (ρ) is plotted on the coordinate axis, and the frequency logarithm function (log ω) on the abscissa axis. The type of such curve also corresponds to the entropic nomogram in Figure 1.

## Lorentz curve of spatial-time dependence

In Lorentz curve[7] the space-time graphic dependence (Figure 4) of the velocity parameter (θ) on the velocity itself (β) is given, which completely corresponds to the entropic nomogram given in Figure 1.

Entropic criteria in economic processes

The concept of thermodynamic probability as a number of microstates corresponding to the given macrostate can be modified as applicable to the processes of economic interactions that directly depend on the parameters of business structures. Thus it is supposed that such number of workers of the business structure is the analog of

thermodynamic probability as applicable to the processes of economic interactions in business. It can be accepted that the total entropy of a business enterprise consists of two entities characterizing a decrease in the competition efficiency (S_1) and a decrease in the personal interest of each worker (S_2), i.e. $S = S_1 + S_2$. S_1 is proportional to the number of workers in the company, $S \propto N$, and S_2 has a complex dependence not only on the number of workers in the company but also on the efficiency of its management.
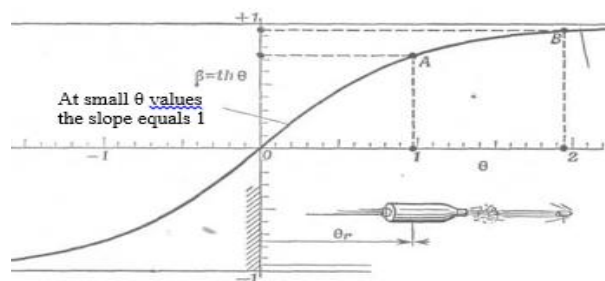
Figure 4. Connection between the velocity parameter (Θ) and velocity itself (β=thΘ)

It is inversely proportional to the personal interest of each worker. Therefore it can be accepted that $S_2 = 1/\gamma$, where γ is the coefficient of personal interest of each worker.

By analogy with Boltzmann's eqn. 1, we have

$$S = \ln\left(\frac{N}{\gamma}\right) \quad (7)$$

In Table 1 one can see the approximate calculations of business entropy by Eqn. 7, for three main levels of business, small, medium and large. At the same time, it is supposed that number *N* corresponds to some average value of the most probable values. When calculating the coefficient of personal interest, it is considered that it can change from 1 (one self-employed worker) to zero (0), if such worker is a deprived slave, and for larger companies it is accepted that $\gamma = 0.1 - 0.01$.

Despite the rather approximate accuracy of such averaged calculations, we can make a resonably reliable conclusion of the fact that business entropy, with the aggregation of its structures, sharply increases during the transition from the medium to large business as the quality of business processes decreases.

**Table 1.** Entropy growth with an increase in business increase.

Structural parameter	Business Size		
	Small	**Medium**	**Large**
$N_1 - N_2$	$10 - 50$	$100 - 1000$	$10000 - 100000$
γ	$0.9 - 0.8$	$0.6 - 0.4$	$0.1 - 0.01$
S	$2.408 - 4.135$	$5.116 - 7.824$	$11.513 - 16.118$
$\langle S \rangle$	3.271	6.470	13.816

Comparing the nomogram of Figure 1 with the data from the Table 1, we can see the additivity of business entropy values (S) with the values of the coefficient of spatial-energy interactions (á), i.e. $S = \alpha$.

S-curves

Some general regularities of the development in biological systems (growth in the number of bacteria colonies, population of insects, weight of the developing fetus, etc.) have been found even in the last century.[8] The curves reflecting these growths were similar. First of all, there are three successive stages, slow increase, fast burst-type growth and stabilization (sometimes decrease).

The engineering systems go through similar stages during their development. The curves drawn up in coordinate system where the numerical values of the important operational characteristics (for example, aircraft speed, electric generator power, etc.) were showed on the vertical and the age of the engineering system/costs of its development was showed on the horizontal axe were called S-curves (by the curve appearance). These curves are sometimes also called life lines. As an example, a graph of the changes in steel specific strength with time (by years) is shown (Figure 5).[8]
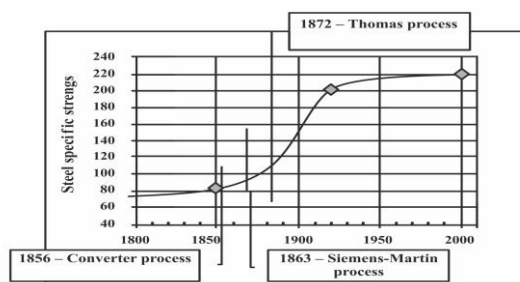

Figure 5. Dependence of steel specific strength on time

Thus, the similarity between *S*-curves and entropic nomogram in Figure 1 is apparent. The time dependence (*t*) is proportional to the reverse of entropy reverse ($1/\alpha$). As applicable to business, such curves characterize the process intensity, for example, sale of the given products. At the same time, entropic nomograms in accordance with Figure 1 assess the business quality (ordinate in such graphs).

Entropic processes in physiological systems

The resources often are closed without exhausting in the real processes when the system starts a more effective similar function and attracts the resources to itself (Figure 6).[8] This is characteristic not only for the short-term processes but also for general development of interstructural and cellular interactions.

It is much more complicated to consider and mathematically analyze the heteromorphic and rather dynamic intercellular and cellular-cellular interactions during ontogenesis. Nevertheless it is possible to reveal some regularities of such energy-molecular and -macromolecular interactions even at early stages of embryogenesis. In particular, relatively stable cellular- cellular interconnections are revealed which can alternate with the manifestations of instability with the activation of cell immigration to the areas of their definitive location.
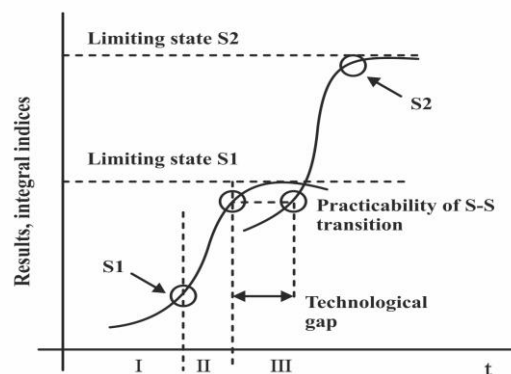
Figure 6. Entropic transitions by time *t*

As examples, stable focal cellular-cellular interconnections in the areas of simple contacts and desmosomes are often based on similar glycoprotein and lipoprotein macromolecular interactions with opposite interaction poles. At the same time, rather unstable selectin and integrin bonds differ in heteromorphism of cellular-cellular bonds or compounds of the proteins indicated with intercellular matrix that increases the instability of such bonds.

The heterotypicity of organization of peptide-peptide and other focal cellular-cellular interactions is more probably accompanied by the manifestation of energetically unstable bonds enhancing the irregularity of biological systems. This, in turn, contributes to forming dynamic and rather unstable compounds facilitating the cell migration and other manifestations of cellular instability. It is the increase in structural diversity, and thus controllable transitory enhancement of the system chaotic character, that can be the basis starting up the transition to new states, to the development individual cells, cell populations in general (in accordance with Figure 6).[9]

It is obvious that, in general, self-organizing processes follow the same principle i.e. slow development from structural diversity, fast growth and stabilization of the renewed biosystem. Thus, the nature fights with entropy development in the organism maintaining it at the constant level as the main condition of stationary state.

Conclusion

As it is known the entropy of isolated systems does not decrease. In open systems the entropy growth is compensated by the negative entropy due to the interaction with the environment.

All the systems discussed above can be considered as open ones. This also refers to spatial-energy processes at which any change in dimensional energy characteristics is conditioned by interactions with external systems. The same is apparently observed in connection with technical and technological systems, in whose development dynamics the additional innovations, modifications and financial investments take place.

The entropy in thermodynamics is considered as the measure of irreversible energy dissipation. From the position of technological and economic principles, entropy is essentially the measure of irrational consumption of energy resources. With the increase in time dependence, such processes stabilize in accordance with nomograms to the most optimal values, together with anti-entropy growth, i.e. the value of $1/\alpha = 1/S$.

The similar growth with time of rationality of technological, economic, and physical and mathematical parameters indicates that their nomograms are universal for the majority of main processes in nature, technology and economics.

Finally, it can be concluded that the idea of entropy is diversified in physical and chemical, economic, engineering and other natural processes which is confirmed by their nomograms.

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