

Invectives against the Entropy Increase Law

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Abstract: *The clarification of the situation with the entropy increase law is blocked by the confusion caused by mixing of concepts of thermal (Clausius') entropy and total entropy (responsible for irreversible processes of any nature). To eliminate this confusion, the thermal entropy increase law and the total entropy increase law should be discussed separately. The first is frankly untenable: Planck, Fermi, and others cite the cases of complete conversion of heat into other forms of energy (the cases with a decrease in thermal entropy). The calculation of total entropy for real systems due to their extreme complexity is impossible, and in the physics literature, only two empirical pillars for the total entropy increase law can be found: (1) observation of thermal processes and (2) observation of changes in the complexity of systems. The observation of thermal processes cannot in principle verify the total entropy increase law since thermal interactions are only a small part of the entire spectrum of interactions. The interpretation of entropy as a measure of disorder, valid for the thermal entropy, for the total entropy of real systems, as proved in the article, is incorrect. Thus, we have no empirical basis to argue that the total entropy increase law is or is not valid. General conclusion: the entropy increase law is the giant fake.*

Keywords: thermal entropy increase law, total entropy increase law, interpretation of thermal entropy as a measure of disorder, interpretation of total entropy as a measure of disorder

1. Introduction

The entropy increase law, understood as the universal law of nature, occupies a central place in the modern scientific world-picture [1. P. 74; 2. P. XIY; 3. P. 516]. Moreover, this law (colloquially referred to as the "law of entropy") in conjunction with the interpretation of entropy as a measure of disorder has fundamentally permeated many aspects of our culture: it appears in stories and novels, plays and films. People's attention is attracted by the apocalyptic tendency of all things to chaos, dictated by the law. In terms of its involvement in cultural life, the concept of entropy probably surpasses all other scientific constructs.

All this takes place despite the fact that the concept of "entropy ... still remains covered with a certain veil of secrecy and misunderstanding" [4. P. 80]. In the scientific and educational literature there are about a dozen basic (generally accepted), but poorly consistent with each other, definitions and interpretations of entropy (their set differs a little from author to author), and several dozen generalizations of the notion of entropy [5. P. 5], with poor knowledge of their application areas.

In the physics literature, the content of the entropy increase law or as it is often called the second law of thermodynamics is even vaguer. Thus K.A. Putilov [6] distinguishes 18 formulations of the second law, Alejandro Morales [7] points to 20 these formulations, and E.G. Oparin [8. P. 28] considers hundreds of those, while, for example, the energy conservation law is formulated in different courses of physics almost identically. The large number of coexisting formulations of the entropy increase law, certainly, indicates the fog of uncertainty in its understanding: "The term "second law of thermodynamics" has been used in physics for more than a hundred years. However, until now different authors use it to mean different content" [9. P. 139].

I suppose that the fog in understanding the entropy increase law can be dispersed by splitting the entropy concept.

2. The total entropy increase law vs. the thermal entropy increase law

The evolution of scientific knowledge, like the entire universal evolution, occurs through the branching of the evolutionary lines (everyone remembers at least the tree of life in the school textbook). Therefore, new scientific results are often born as a result of the splitting (branching) of scientific concepts. Let me illustrate this point with the example of classical mechanics.

In the works of Isaac Newton's predecessors, the theory of motion was forced to be limited to a qualitative consideration. This happened because the basic concepts were mixed up. Firstly, the concepts of mass and weight of body were considered within the framework of one unsplit "bush of concepts". Secondly, in the framework of another unsplit "bush of concepts", the concepts of strength, momentum, and energy were discussed. Thirdly, the concepts of speed and acceleration of movement did not distinguish. Only when all these concepts were split, did Newton get the opportunity to formulate his laws and write out the equations of classical mechanics.

With the entropy increase Law, I suppose the situation is the same: the entropy concept must be split into the concepts of the thermal and total entropy. Total entropy is responsible for irreversible processes of any nature, while thermal entropy (the Clausius entropy) supervises only thermal processes. As an illustrative example, we can give the mixing of different gases at the same temperature. There are no thermal changes, why the thermal entropy remains unchanged, while the total entropy, due to the irreversibility of the process, changes. Mixing of gases, which were initially at different temperatures, occurs with a change in both the total and thermal entropies.

Rudolf Clausius introduced the concept of entropy in 1865 [10] and in the same article declared that "the entropy of the universe tends to a maximum". Wherein, he could mean only thermal entropy, because he did not know other

entropies then. So actually Clausius spoke of the thermal entropy increase Law.

The expansion of the entropy increase law to irreversible processes of any nature, when it comes to de facto total entropy increase, was promoted more than by others by Max Planck. Starting with his doctoral dissertation "On the Second Law of the Mechanical Theory of Heat" (1879), he insisted on the fact that an increase in entropy occurs "in all nature processes" [11. S. 96]. That thought was very important to him. I think it was that idea that Planck had in the back of his mind when in the 1920 in his Nobel lecture he regretted that new ideas triumph in science not through discussion, but as a result of the natural extinction of the carriers of the old ones. He had no reason to complain about the perception by the scientific community of the quantum idea.

Planck's efforts were not in vain, other authors followed him, although not immediately. For example, Lev Davidovich Landau and Evgeny Mikhailovich Lifshits, in their course of statistical physics, extend the entropy increase law to "all irreversible processes that occur with macroscopic bodies" [12. P. 49].

It would seem obvious that the propagation of the entropy increase law to irreversible processes of any nature requires a clear differentiation between thermal entropy for thermal phenomena and total entropy for the whole set of phenomena. Alas, such a differentiation is not made in the physics literature; the concept of entropy remains unsplit (blurred). The authors do not stipulate which entropy — total or thermal — they discuss in particular situations. And it is completely incomprehensible which of these two laws they consider to be the universal law of nature. This non-splitting of the concept of entropy, in particular when the entropy increase law is interpreted as the second law of THERMODYNAMICS, is a characteristic of all physics courses (about 70) that I have studied on this subject.

Now, we will separately make sense out of the thermal entropy increase law and of the total entropy increase law.

3. Invalidity of the Thermal Entropy Increase Law

3.1. Determination of thermal entropy

Thermal entropy (the Clausius entropy) is introduced by the expression

$$dS = \frac{dQ}{T}.$$

Here dQ is a small increment of the amount of heat Q in the system; dS — small increment of its thermal entropy S ; T — absolute temperature. The crucial thing for our consideration is that according to (1), if the amount of heat in the system decreases, then its thermal entropy decreases, and vice versa.

3.2. Examples proving invalidity of the thermal entropy increase law

The first example: the expansion of an ideal gas at a constant temperature. Once again, let's rely on Planck's statement:

"If a perfect gas be allowed to expand, doing external work, and be prevented from cooling by connecting it with a heat-reservoir of higher temperature, the temperature of the gas, and the same time its internal energy, remains unchanged, and it may be said that the amount of heat given out by the reservoir is completely changed into work without an exchange of energy taking place anywhere." [11. S. 74].

As we can see, Planck explicitly speaks here about the complete conversion of heat into work (into other forms of energy). This example, in the same vein, is considered by Enrico Fermi in his "Thermodynamics":

"Consider, for example, the isothermal expansion of an ideal gas that is kept in thermal contact with a source of a heat at the temperature T . Since the energy of the [ideal] gas depend only on the temperature, and the temperature does not change during the process, we must have $\Delta U = 0$. From the first law... [the law of energy conservation], we obtain, then, $L = Q$. That is, the work, L , performed by the expanding gas is equal to the heat Q which it absorbs from the source. There is thus a complete transformation of heat, Q , into work L ." [13. P. 30].

Other authors also give this example.

It was said above that with a decrease in the amount of heat in the system, its entropy of Clausius decreases. So here, we have an decrease in thermal entropy.

The second example: the flow of an ideal gas in a tapering pipe. For geometric reasons, this flow is accelerated. Herewith, according to the Bernoulli equation,

$$\frac{v^2}{2} + c_p T = const$$

(v is the flow velocity, c_p is the specific heat capacity of the gas at constant pressure), the flow is cooled, which means, according to (1), a decrease in its thermal entropy.

There are also other examples proving the invalidity of the thermal entropy increase law.

3.3. Summary

Among other things, the invalidity of the thermal entropy increase law removes the "spell" from heat engines without a cold reservoir, that is, from the perpetual motion engines of the second kind, the efficiency of which is not limited by the Carnot efficiency and on the basis of which, therefore, can be built the thermocyclic power engineering that carries out the heat cycle. The transition to this power engineering will not only eliminate the anthropogenic factors of climate warming but also will minimize the consumption of hydrocarbons and other non-renewable energy resources [14–16].

Above, we have defined thermal entropy by the expression (1). Let's note, however, that Clausius and other founders of thermodynamics considered, as it is also considered today, this definition working only in equilibrium or quasi-equilibrium state. And it is easy to understand why: the Clausius entropy does not "catch" the redistribution of heat in the system with a constant value of the total amount of

heat in it, when hot fragments of the system share the heat with cold fragments. In the equilibrium state, heat redistribution does not occur.

The reader is entitled to ask why, in this article, I allow myself to restrict myself to the definition of thermal entropy (1)? Answer: because the quasi-equilibrium approximation is enough when considering many thermodynamic issues. Say, definition (1) has been successfully used to this day in the analysis of thermal machines. When considering the above examples leading to the conclusion that the thermal entropy increase law is invalid, the quasi-equilibrium approximation is also correct.

Besides, I simply did not find in the physics literature a definition of thermal entropy, acting in the general irreversible case. None of the founders of thermodynamics and statistical physics, as far as I know, took care of this. Such a generalization was proposed by the author of these lines [15. P. 74–75; 16], however, this generalization is not directly related to the plot of this article.

4. The insoluble problems with the empirical verification of the total entropy increase law

In this section, for brevity sake we will sometimes omit the definition “total” in the term “total entropy”.

4.1. The definition of the total entropy

The Gibbs entropy of a physical system is determined by the expression

$$S = -k \int \rho(q, p) \ln \rho(q, p) dqdp,$$

where $f(q, p)$ is the distribution function of the system in the phase space of all its coordinates q and momenta p , and k is the Boltzmann constant. Being determined on the distributions of values of coordinates and momenta, the Gibbs entropy is introduced as part of the mechanical description and is not applicable when the occurring in the system processes are not reduced to the movement of its particles and parts. The total entropy of the system can be written as

$$S = -k \int f(x) \ln f(x) dx,$$

where $f(x)$ is the distribution of values x , x is the set of all independent variables describing the system, mechanical q , p , and non-mechanical X .

4.2. The impossibility of the real systems total entropy calculation

The calculation of the total entropy of real systems requires taking into account all the interactions acting in them, which is impossible. Even for very simple mechanical systems, the change in the phase volume, produced by the interactions, in the general case cannot be calculated. The development of the dynamic chaos theory and synergetics has shown that already a mechanical system with a very small number of degrees of freedom performs, generally speaking, a stochastic, in the irreversible case fractal, movement, which by its nature is unpredictable and which we can only step by step “sketched” using a computer in a calculating experiment. What can we say then of mechanical systems

with a large number of degrees of freedom! For non-mechanical systems, for which the movement of their constituent particles and parts is not essential (chemical, organic, social), the calculation of the total entropy still more complicated.

In physics courses, the entropy increase is often illustrated by specially constructed simple examples. There are also estimates of changes in entropy for a particular real systems. However, in all these cases the estimations of the change in entropy are carried out assuming the validity of some extremely simple models, such as the ideal gas model, which have very little in common with reality. All these estimates are too rough to be used to judge the change in the entropy of real systems.

4.3. The special role of the interpretation of entropy as a measure of disorder in the empirical justification of the total entropy increase law

For the reason stated in Sect. 4.2, in physics literature for the past century and a half, the total entropy increase law has been based not on calculating the entropy of real systems, but on two empirical pillars: firstly, on the analysis of the thermal balance of the observed systems; secondly, on the estimations of the changes in their complexity/disorder in conjunction with the interpretation of entropy as a measure of disorder.

Observations of the balance of the thermal processes, which speak of thermal entropy change, cannot in principle verify the total entropy increase law since thermal interactions are only a small part of the entire spectrum of interactions. And all would be fine, but the estimations of the changes in the complexity/disorder of real systems are also useless in this regard for the reason that, as it will be shown below, for the real systems the total entropy is not a measure of disorder.

4.4. The historical roots of the interpretation of entropy as a measure of disorder

As it is stated in the preamble of the article, the entropy increase law in conjunction with the interpretation of entropy as a measure of disorder occupies a central place in the modern scientific world-picture. Let’s note, however, the startling fact that the validity of this interpretation for real systems has never been proved. No one has even discussed the conjunction between entropy and disorder seriously. The founders of thermodynamics and statistical physics only concerned this conjunction, considering it, apparently, obvious.

Introducing the concept of entropy in 1865 [10], Clausius interprets its increase as a tendency to equalize the temperature in volume. The same idea is present in “Theory of Heat” by James C. Maxwell of 1871 [17. P. 308–309]. In the article by Ludwig Boltzmann of 1877 [18], the entropy is linked to the uniformity of the distribution that describes the system. And in “Lectures on Gas Theory”, published 20 years later [19], he already connects the probability of a state (and, consequently, entropy – see Sect. 5) with the disorder. Boltzmann here speaks of the connection between entropy (state probability) and disorder as if in passing, how

about obvious. Apparently, by that time this connection had already become quite a commonplace, and did not cause much scientific interest. To confirm this statement, it can be indicated, for example, that Hermann Helmholtz in 1883, that is, in the interval between the two mentioned works by Boltzmann, speaks of entropy as a measure of disorganization [20. S. 972]. And, like other authors, he does not focus on this point. Since that time, scientists have discussed in detail only the apocalyptic consequences of this indisputable for all connection, — the inevitable cessation of all Universe processes in general chaos and the impending death of all living things on Earth.

This whole situation with the interpretation of entropy as a measure of disorder may seem strange, but such cases in science are quite common, well studied and are classified as tacit (terminology of Michael Polanyi) or background (Karl Popper) knowledge, on which scientific knowledge is based and which, because of its "evidence" is not discussed. I assume that the problems with the interpretation of entropy as a measure of disorder arose because of the same mixing (non-distinction) of concepts of thermal and complete entropy, which we discussed in Sect. 2.

4.5. Implicit (not discussed out loud) grounds of the interpretation of entropy as a measures of disorder

The Clausius entropy is undeniably a measure of disorder: the more heat a system contains and the more its thermal entropy is, as it is defined by (1), the more disorder there is in the system, since heat is the random motion of the particles. This consideration, valid only and exclusively concerning the Clausius thermal entropy, was transferred without the deliberation to the total entropy. Because of the unclarity of situation with the thermal and total entropies, caused by non-distinction (mixing) of these concepts, physicists pushed the justification of the interpretation of entropy as a measures of disorder into the subconscious, that is, into the realm of tacit knowledge.

It is clear, that the property of the Clausius entropy to be a measure of disorder does not refer to total entropy, because the former and the latter are different physical quantities. However, this does not yet make the interpretation of total entropy as a measure of disorder invalid, since there remains the argument, connected with the expression of total entropy through the phase volume of the system. This argument is found in the physics literature, but I do not know who proposed it first. Its meaning is as follows.

Following the calculating techniques of statistical physics, we pass from the total entropy (4) to the determination of entropy through the phase volume of system. For the distribution function of system $\rho(x)$, with an average value $\rho(x)_{mean}$, normalized, as is customary, to unity, so that the "volume" under the "surface" $\rho(x)$ is equal to 1, "width" Δx of the distribution $\rho(x)$ is entered as the "width" of the "rectangle" with height $\rho(x)_{mean}$ and unit "volume": $\rho(x)_{mean} \Delta x = 1$. Exactly the quantity Δx is called the phase volume.

Entropy S of distribution $\rho(x)$ is defined as logarithm of the phase volume of the system taken with the proportionality coefficient k :

$$S = k \ln \Delta x.$$

Given the approximate equality

$$S = \ln[\rho(x)_{mean}] \approx \ln^{mean} \rho(x),$$

that is,

$$\ln \int \rho(x) \rho(x) dx \approx \int \rho(x) \ln \rho(x) dx,$$

we get

$$S = k \ln \Delta x = k \ln \frac{1}{\rho(x)_{mean}} = -k \ln[\rho(x)_{mean}] \approx -k \ln^{mean} \rho(x) = -k \int \rho(x) \ln \rho(x) dx,$$

that is, total entropy (4).

Thus, the entropy of the distribution, describing a system, characterizes its "width" ("smearing"): a wider distribution has a greater entropy, wherein a more complex (in form) distribution has a smaller width. This reasoning, after splitting entropy into total and thermal entropies, remains the only argument in favor of interpretation of total entropy as a measure of disorder. Let's show further its invalidity.

4.6. Invalidity of interpretation of total entropy as a measure of disorder for real systems

4.6.1. Brief review of contemporary works on the problem

The identity of entropy with disorder not only has never been proved by anyone (see Sect. 4.4), but it directly contradicts the actual observable facts, because the evolution of the observed world — inorganic, organic, and social — does not go towards simplifying the evolving systems, as this interpretation of entropy in combination with the entropy increase law prescribes, but it goes in the exact opposite direction. In the last third of the XX — beginning of the XXI centuries, the contradiction of the discussed interpretation of entropy to actual facts prompted a number of researchers to question this interpretation. These scientists can be divided into two groups.

Scientists of the first group argue that an increase in entropy can be accompanied by an increase in complexity even of isolated systems. Some authors blame the concept of disorder/complexity for the difficulties that arise, proposing to correct this concept (P. Wright, St. Beer, S.M. Stishov) or even completely abandon it (N. Georgescu-Roegen), others encroach the concept of entropy by modernizing (A.M. Hazen, A.P. Levich) or yet rejecting it (M.I. Shterenberg). Ya.B. Zeldovich and I.D. Novikov, as well as A.N. Panchenkov, explain the complication of spatial structures by the simplification of impact ones. E.A. Sedov compensates the dissipation of thermal energy by the concentration of mass under the influence of gravitational forces. In later works, he connects the ordering of matter at the upper levels of the structural organization with its disordering at the lower ones. P.T. Landsberg (see more in Sect. 4.6.3) supposes that a decrease of distribution entropy caused by a complication of its shape can be surpassed by an increase in entropy caused by a widening the distribution due to an increase of the number of possible microstates. Their own versions of this idea are expressed by D. Layzer, J.S. Wicken (see more in Sect. 4.6.3), S. Frautschi. F.A. Tsitsin concludes that it is possible to decrease the entropy

of an isolated system with a simultaneous increase of the probability of its state. He explains the occurrence of the discrepancy between entropy and the probability of a state by an entropy fluctuations.

Scientists of the second group explain the evolutionary complication by the pressure of interactions. I. Newton, I. Kant, and P. Laplace had already adhered this point of view, when speaking specifically about gravity. Nonetheless, they naturally did not correlate the idea of evolutionary complication with the entropy increase law, which was formulated later. However, S.G. Suvorov, I.L. Genkin, C.M. Caves, M.N. Matveev, R. Penrose, B.J. Ackerson, as well the aforementioned M.I. Shterenberg, do correlate of this idea with this law.

According to scientific standards, the links to all mentioned works should be given here, however, this would have lengthened the list of references too much. The reader will find more detailed information about these publications in our works, indicated in the next paragraph.

The authors of the works, we have just discussed, to one degree or another, come closer to understanding that the increase in complexity does not contradict the increase of entropy, but none of these authors declared the interpretation of entropy as a measure of disorder as invalid. As far as I know, only three authors independently declared the invalidity of this interpretation: the Soviet scientist Yuriy Petrovich Petrov [21], Kenneth Denbigh [22, 23], a member of the Royal Society of London, and the one who writes these lines [15. P. 184–264; 24; 25. P. 299–366; 26. P. 82–115]. Further, we briefly reproduce the considerations leading to the conclusion that the interpretation of total entropy as a measure of disorder is invalid.

4.6.2. The role of interactions

The general thesis, which we will further substantiate: the argument in defense of the interpretation of entropy as a measure of disorder associated with relations (5–8) in Sect. 4.5, works only when the interactions are off (ideal gas) or fixed (not changing in time), while in real systems, in the general case, interactions varying in time are present, which makes the relationship between entropy and disorder ambiguous. To begin with, let's illustrate this thesis using the Gibbs equilibrium distribution. Its shape is determined by the Hamiltonian, fixing the interactions acting in the system:

$$\rho(q, p) = A \exp \left[-\frac{H(q, p)}{kT} \right]$$

(q — coordinates, p — impacts, k — the Boltzmann constant, A — the normalization constant, T — absolute temperature). If $H(q, p) = 0$, that is, if the system is a gas of non-interacting points, then $\rho(q, p) \equiv const$, so that these points are randomly distributed both in the coordinate space and in the impact space. This is a case of complete chaos.

If we consider material points to have only kinetic energy $mv^2/2$ (m is the mass of the point, v is its velocity), then the equilibrium distribution in the coordinate space remains chaotic, however, in the space of velocities it becomes ordered, acquiring the form of the Maxwell distribution

$$\rho_v = a \exp \left[-\frac{m(v_x^2 + v_y^2 + v_z^2)}{2kT} \right]$$

(x, y, z — coordinates, v_x, v_y, v_z — components of the velocity vector, a — the normalization constant). The width of this distribution is the greater, the higher the temperature of the gas is, that is, the more random the movement of its molecules is and, therefore, the more chaotic the system is.

When we place the gas of material points also in the Earth's gravitational field, so that they obtain the potential energy mgz (g — is the acceleration of Earth's gravity), the equilibrium distribution, while remaining Maxwellian in the space of velocities, acquires ordering in the space of coordinates, taking the form of the Boltzmann distribution:

$$\rho_z = b \exp \left(-\frac{mgz}{kT} \right),$$

where b is the normalization constant.

We see that under the fixed conditions in which the given system exists, the distribution that describes it turns out to be the widest (most homogeneous, most chaotic) among distributions PERMITTED BY INTERACTIONS. We may perceive this phenomenon in some cases as a simplification, and in others as complication of the system, because we make our estimates of the complexity/disorder of real systems by sight, without taking into account the field interactions that are not amenable to visual perception.

The complication/simplification of the system, that is the formation/destruction of structures, means the complication/simplification of the pattern of the interactions acting in the system. When the interactions that determine the form of the distributions describing a system develop together with the system, as is usually the case with real systems, it is impossible to insist that the development of the system is accompanied with its indispensable simplification. If at first chaos prevails in the system, then interactions will bring it into a more ordered state. This is how the fractal cosmic and other structures arose during the evolution of the observed world. If the initial state was "overcomplicated", then over time it will simplify to a certain level optimal for these interactions and external conditions. For example, if we pulled tightly together the electric charges of the same sign and then left them free, then due to mutual repulsion, they would diverge around, so that the distribution describing the system would become wider (more uniform).

Let's now place electrically positive and negatively charged particles in the vessel. Electrical interactions limit the movement of particles, not allowing them to have the speeds "they want." The pairing of particles into electrically neutral molecules changes the situation. Such molecules no longer interact with each other at a distance (we neglect their gravitational interaction), that is, they do not limit mutual displacements, and due to this, the phase volume (entropy) of the system increases. Of course, the particles are now constrained by the fact that they move only in pairs, and due to this, the phase volume (entropy) decreases. It is important that the association of particles can be either beneficial to the system in terms of the formation of stable structures, or disadvantageous to it, depending on specific conditions — temperature, pressure, etc. So, the high temperature makes electrically charged particles weakly susceptible to electrical interaction, preventing the formation of molecules, and vice versa. Molecules are material structures whose formation (that is, complication) can correspond to both an increase in

entropy (an increase in the phase volume of the system) and a decrease in it. This situation is general.

Recall that the idea of the greatest probability of uniform distribution (of “chaos”) is due to incorrect dissemination of the principle of equiprobability of microstates beyond the ideal gas model. Only within the framework of this model, the equilibrium distribution does come down to the Maxwell distribution in velocities and to uniform distribution in coordinates. Outside the ideal gas model, this principle is false, and the statement about the greatest probability of the uniform distribution is untenable.

In the ideal gas model, the internal energy of the system is reduced to the kinetic energy of the random motion of molecules, that is, to thermal energy. However, as stated in Sect. 4.5, thermal entropy is a measure of disorder. Thus, when we leave the ideal gas model, we leave the interpretation of total entropy as a measure of disorder.

4.6.3. The role of the number of microstates

Mentioned in Sect. 4.6.1 Peter Landsberg [27, 28] argues that the complication of the system can occur with an increase in the (total) entropy of the system due to an increase in the number of its possible microstates. He postulates for the disorder D and the entropy S not the relation $S = k \log D$, as some authors do, but the relation

$$D(n) = \frac{S}{S_{max}} = \frac{S(n)}{k \ln n(t)}, \quad 0 \leq D(n) \leq 1,$$

where n is the number of possible microstates of the system.

For order $1 - D$ we have

$$1 - D = 1 - \frac{S}{S_{max}}.$$

Landsberg writes, that in real-life situations, $S(n)$ can grow slower in time than $k \ln n(t)$, so that the rate of change of disorder

$$\dot{D}(n) = \left[\frac{\dot{S}(n)}{S(n)} - \frac{\dot{n}}{n \ln n} \right] D(n)$$

(the dot above the letter means the time derivative) may be negative even if $\dot{S}(n)$ is positive.

The idea similar to Landsberg’s idea is expressed by David Layzer [29, 30].

The concept of order/disorder is introduced intuitively, so definition (12) is in principle no worse than definition $S = k \log D$, differing from it by the linearity of the relationship between D and S , and normalization of D to unity.

It is this normalization, due to which the denominator $k \ln n(t)$ appears in definition (12), and allows, if we reason formally, an increase in the order $1 - D$ with an increase in the entropy S . In terms of content, Landsberg’s thought is transparent. We know that the entropy of a distribution is greater, the wider the distribution is, and that the distribution is wider, the simpler it is in shape (see Sect. 4.5). Landsberg supposes that a decrease in the entropy of a distribution, caused by a complication of its shape, can be surpassed by an increase in entropy caused by an extension of the distribution due to an increase of the number of possible microstates (see the illustration).

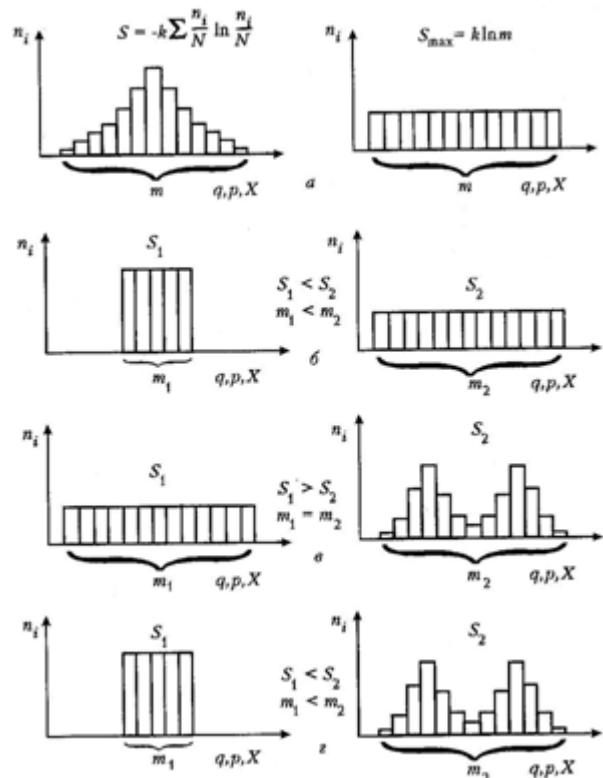


Illustration (by the author of these lines) of the affirmation of P.T. Landsberg, who supposes that a decrease in the entropy of a distribution caused by a complication of its shape can be surpassed by an increase in entropy caused by an extension of the distribution due to an increase in the number of possible microstates.

Jeffrey Wicken [31, 32] offers a concrete version of Landsberg's idea. Considering the process of formation of polymer molecules from monomers, he shows that this process can proceed with an increase in entropy due to an increase of the number of configuration possibilities, available for the system. Wicken illustrates his point with the following example. Let’s suppose that we have monomer molecules A, B, C, and D in equal quantities. Let’s suppose further, that a certain part of monomer molecules of all four types has formed dimers. In total, therefore, we have 20 types of molecules — 4 types of monomers and 16 types of dimers:

A	B	C	D
AA	BA	CA	DA
AB	BB	CB	DB
AC	BC	CC	DC
AD	BD	CD	DD

Based on the Boltzmann principle $S = k \ln W$, Wicken introduces the entropy of a system as a quantity, proportional to the logarithm of the number of combinations that can be formed from all molecules (monomers and dimers). He discovers that this entropy is maximum at the certain fraction of the molecules that form the dimers so that with a smaller value of this fraction, their formation occurs with an increase in entropy.

Let’s consider this in more detail. Wicken starts with Boltzmann's expression

$$W = \frac{N!}{n_1! n_2! \dots}$$

for the number of microstates of an ideal gas. Denoting by M the number of molecules-monomers of each of the four types A, B, C, and D and by ξ – the fraction of molecules in all four types, which have formed dimers, we have after their formation $M(1-\xi)$ of molecules A, B, C, and D. Further, $4M\xi$ of molecules-monomers has formed $2M\xi$ of molecules-dimers, that is, we have $(2M\xi/16) = (M\xi/8)$ of molecules-dimers for each of 16 types. The total number of molecules-dimers of different types is $4M(1-\xi) + 2M\xi = 2M(2-\xi)$. We calculate, using (15), the total number of combinations that can be formed from all molecules (monomers and dimers):

$$W_0 = \frac{[2M(2-\xi)]!}{[M(1-\xi)]^4 (M\xi/8)!^{16}}$$

Investigating the entropy

$$S_0 = k \ln W_0$$

of a system as the function of ξ , Wicken finds that it has maximum at $\xi = 0,553$. This implies that the combining of monomers into dimers, associated with the increase of ξ from 0 to any value equal to or less than 0,533, occurs with the increase of entropy.

Supporting the conclusion of Wicken that the formation of molecules-polymers can occur both with a decrease in entropy and with its increase, we should nevertheless note that the specific expression (15) used by him is valid only for a model of a gas of noninteracting particles and is not applicable to real systems, the entire development of which, including the formation of polymers, is carried out precisely due to the interaction of particles.

4.6.4. The role of the variables number

Let's use Landsberg's idea, but let's talk about changing not of the number of possible microstates, which makes sense only in the equilibrium case, but of the number of independent variables, which describe the system.

The patterns of interactions acting in real systems change with the development of these systems in an unpredictable way, what makes also unpredictable the change in time of the number of independent variables describing systems.

It should be emphasized, that a change in the number of variables itself entails a change in the entropy of the system regardless of its complexity. If the entropy of the system increases, then this may be caused simply by an increase in the number of variables describing the system. In this case, the complexity of the distribution describing the system can decrease, what makes an additional contribution to the extension of the distribution, that is, to the increase of entropy. However the complexity of the distribution can also grow—if the decrease in total entropy associated with the growth of complexity is outweighed by the extension of the distribution due to the increase of the number of variables. So, because of the increase in the number of independent variables describing real material systems, an increase in their entropy can be accompanied by both a decrease in the complexity of the systems and its increase.

4.6.5. Summary

We conclude Sect. 4.6. The interpretation of (total) entropy as a measure of disorder is based on two implicit (not discussed out loud) pillars:

- 1) Thermal entropy is a measure of disorder since heat is the random movement of particles;
- 2) Total entropy of distribution is a measure of its width: a wider distribution has a greater entropy, wherein a more complex (in form) distribution has a smaller width.

The first pillar is illusory, since the interpretation of entropy as a measure of disorder interests us only in terms of verifying the TOTAL entropy increase law, while the thermal entropy increase law is invalid. The second pillar, as applied to real systems, also disappears due to the interactions inside each of them. The interpretation of total entropy as a measure of disorder is valid only when interactions are turned off (the ideal gas model) or fixed (not changing in time) whereas in the general case interactions inside real systems change in time, what makes the relationship of the total entropy and the complexity of real systems ambiguous; with the increase of the total entropy of the real system its complexity can both decrease and increase.

4.7. Conclusion: the total entropy increase law does not have an empirical base

As stated in Sect. 4.3, for the last century and a half the verification of total entropy increase law has been grounded on:

- 1) estimations of the changes in thermal entropy, that is, the consideration of thermal changes in observed systems;
- 2) estimations of the changes in the complexity/disorder of the observed systems with the further use of the interpretation of entropy as a measure of disorder.

The first pillar disappears, because the observation of thermal processes, due to their particular nature, in principle cannot verify the total entropy increase law (thermal interactions are only a small part of the entire spectrum of interactions). The second pillar disappears also because the interpretation of total entropy as a measure of disorder for real systems is invalid. It should be added that the total entropy of real systems due to their exorbitant complexity cannot be calculated. For a combination of these reasons, we have no empirical basis to argue that the total entropy increase law is or is not a universal law of nature.

As stated in the preamble to this article, several dozen modifications and generalizations of the concept of entropy exist in the physics literature. However, it does not follow from anywhere that for entropy, modified or generalized in one way or another, the law of its increase works better than for "ordinary" physical entropy (3) or (4).

5. General Conclusion: The Entropy Increase Law is the Giant Fake

The foregoing leads to the conclusion that the entropy increase law is absolutely exceptional case in the science. It is the case of statement that has acquired the status of the

universal and even main law of nature without strong empirical basis or, strictly speaking, without any empirical basis. This means that the entropy increase law is the figment of scientists' imagination. It can also be said that this is the giant fake. This law, I suppose, will sooner or later be removed from the scientific world-picture. At most, it can remain in science as an interesting puzzle in the history of science: it would be necessary to explain how this giant fake with the active participation of a whole cohort of remarkable scientists and with passive approval of the entire scientific community occurred?

In my opinion, a fatal role in the destiny of the entropy increase law has played the Boltzmann principle. Defining entropy in the article of 1877 [18] with the expression $S = k \ln W$ (although Boltzmann did not record the own principle in this form literally, exactly this formula is engraved on his gravestone as the Master's highest achievement) and calling the quantity W in it (by the definition, W always grow) macrostate probability of system, Boltzmann de facto introduced the entropy increase law as a consequence of his own DEFINITION of entropy.

On the part of Boltzmann, this was a deeply mistaken move, which led the scientific community astray from the "righteous" path, what, of course, Boltzmann did not realize. Instead of continuing to doubt the entropy increase law and seek arguments to confirm or to deny it, the scientific community, seduced by Boltzmann, accepted its principle, finally believing, without any empirical basis, that this law is the universal law of nature. In fact, the faith in this law has rested for a century and a half on the faith in the general (universal) evolution in a certain direction. We simply introduce the probability of macrostate W of a system, which by definition always grows, and call by entropy the quantity proportional to the logarithm of W : $S = k \ln W$.

Now it turns out that the faith in general (universal) evolution in a certain direction has paid off, while faith in the total entropy increase law has not. Drawn by this law in conjunction with the interpretation of entropy as a measure of disorder, the apocalyptic development of all things towards chaos does not correspond to reality. The evolution of the observed world is exactly happening, and it is exactly happening in a certain direction, only just this direction is opposite to what is dictated by the entropy increase law: universal evolution does not go towards increasing general chaos but towards increasing complexity. In this regard, the evolutionary future does not threaten anything bad to humanity.

In the XIX century in various fields of natural sciences, the evolutionary ideas won. The entropy increase law is the reaction of physicists to the evolutionary constructions of nonphysicists, but this reaction is, to put it mildly, inadequate. By removing this law together with the Boltzmann principle from the scientific world-picture, we will make it more adequate (more realistic).

And the last point. The history of the entropy increase law confirms in the most visual way the validity of the principle of fallibilism by Karl Popper et al., according to which any scientific theory, including the most fundamental and

generally accepted, may turn up wrong tomorrow will make it more adequate (more realistic).

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