Monatshefte für Chemie - Chemical Monthly (2021) 152:871–879
https://doi.org/10.1007/s00706-021-02803-w

REVIEW

How many laws has thermodynamics? What is the sense of the entropy notion? Implications for molecular physical chemistry

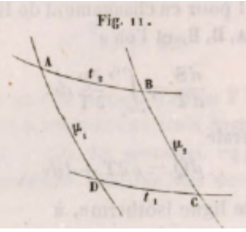
Evgeni B. Starikov[1,2]

Received: 27 October 2020 / Accepted: 21 June 2021 / Published online: 6 August 2021

Abstract

Around two hundred years of thermodynamics' history have been re-analyzed. The priority of thermodynamics by Carnot for the modern scientific research has been stressed.

Graphic abstract



Keywords Thermodynamics · Energetics · Entropy · Enthalpy · Compensation

Introduction

After reading the title any attentive reader would immediately exclaim:

> *Is everything OK with the author? The answer to the first poser is well known since years: There are FOUR of them. Please, open the book by one of the international authorities in the field* [1] *and try to learn by rote what he has written.*

Entropy means nothing more and nothing less than Disorder in the basic, fundamental, general sense of the word. All other definitions are either fanciful fiction or simply fake.

The notoriety of such a standpoint has already truly long and rich history. Meanwhile, its stubbornly successive manutention owing to its inherent logical '*sleights of hand*' is sticking out a mile (we cite here, e.g., the *Preface* to the work [2]):

> *"Entropy now finds a place in school curricula and seems understandable enough, at least in a qualitative way, in terms of probability and disorder. Many teachers must have found Professor George Porter's admirable films helpful in this respect.*[1] *Yet there are some difficulties along the way: the q/T formula is usually pulled out of a hat at some stage or other, and anxiety may well be felt about the precise evaluation of 'randomness' or 'probability' in a particular case.*
>
> *In seeking an intuitive feeling for the relationship between q/T and 'probability', a teacher will soon find himself in the deep water between classical thermodynamics and statistical mechanics. A word or two of explanation may therefore be in place here. Relationships between energy, volume, entropy, heat capacity, etc., lie in the province of classical thermodynamics,*

✉ Evgeni B. Starikov
starikow@port.kobe-u.ac.jp

[1] Chemistry and Chemical Engineering, Chalmers University of Technology, Göteborg, Sweden

[2] Graduate School of System Informatics, Kobe University, 1-1 Rokkodai, Nada, Kobe 657-8501, Japan

---

[1] *The laws of disorder* (3 parts), obtainable from ICI Film Library, Thames House, North Millbank, London, SW1.

and many such relationships are derivable exactly from the laws of thermodynamics. Given the laws, one simply accepts the formulae as correctly derived and becomes more or less proficient at remembering the physical implications when a specific problem arises; but beyond that there is no essential understanding involved. A chemist who seeks to understand chemical equilibrium has to look beyond classical thermodynamics to elementary statistical mechanics, where thermodynamic properties and even the laws themselves are explained in molecular terms. That being so, it is helpful to relate the thermodynamic side of chemistry wherever possible to molecular behaviour. By way of encouragement to those who may have no confidence after struggling for many years with elementary thermodynamics, here at the outset is a statement by the late Professor E. A. Guggenheim[2]:

'The reviewer [E. A. G.] regards statistical mechanics as something he understands, or thinks he understands; but he regards thermodynamics as something which he can only understand through statistical mechanics'.

The present difficulty for the teacher is that q/T is approached through thermodynamics and probability through statistical mechanics and the link is made at a fairly remote level. I have therefore attempted here to sketch a more direct and unified approach to serve as a connected background for teachers. It builds frankly upon the molecular structure of matter and has the limited objective of demonstrating the direct relationship of ΔH-TΔS and of the familiar form of the equilibrium constant to the principle of increasing entropy, to be understood in terms of quantum states. The only point at which I am conscious of a logical sleight of hand for the sake of a short cut is at the identification of $(V_2/V_1)^L$ *for a mole of gas with a ratio of numbers of quantum states; but in general the central theme is so straightforward that I am appalled at the number of words taken to set it down. For this reason, the reader should circumvent troublesome passages, putting them down to bad writing, and read on to get the whole argument in rapid perspective. Those moderately familiar with the substance of the first chapter could well begin at chapter 2.*

Atomic and molecular quantum states are already incorporated into the elementary exposition of atomic structure and valence, and the extension to counting the combinations of such states in macroscopic systems, despite some pitfalls, does not seem such a very large step and has the virtue of leading directly towards advanced studies. Just how much of the argument can be passed on to sixth-formers it is hard to guess, but recent experience suggest that what is unfamiliar and even difficult for teachers (confused perhaps by their early experience) may be quite acceptable to their pupils.

My thanks are due to Professor P. G. Ashmore and to several teachers who kindly offered helpful comments on the manuscript.

P. A. H. Wyatt.

St. Andrews

November 1970"

Sorry, people, there is but much-much more to the story [3]. While Atkins skillfully guides the readership 'from the fascinating theory of entropy (revealing how its unstoppable rise constitutes the engine of the universe), through the concept of free energy, and to the brink, and then beyond the brink, of absolute zero', he comes to his wit's end, when it becomes necessary to clearly formulate, (a) what the physical sense of the Entropy notion should actually be; (b) why in reality it is so difficult to approach and sheer impossible to go beyond 'the brink, the absolute zero'.

The following is anyway not a rebuke to Atkins' address. Instead, it is rather an appeal to young, active, and proactive research workers not to stop at any arbitrary point. Based upon the most recently found mine of widely unknown or simply well-forgotten information about thermodynamics [3], we shall concisely but thoroughly re-analyze here the well-known historical facts to try producing a valid and handy outlook.

Why is it necessary at all? We do re-open the scientific research horizons this way [4].

How the number of basic laws could start being more than one in Thermodynamics, of all the scientific research branches?

Reading carefully the thorough, profound, authoritative historical analyses by Stephen G. Brush and Dirk ter Haar (1919–2002) [5, 6], apart from other literature on the theme, we shall not find a direct and clear answer to the above poser.

Still, re-reading well-known works by undoubted peers we could still manage tracing the story back to the fact. Indeed, it is in his seminal 1847 report '*Erhaltung der Kraft*' that Helmholtz has started speaking about '*a number of laws theoretically derived by Carnot and Clapeyron*' in referring to Clapeyron's paper devoted to the analysis of the famous

---

[2] Trans. Faraday Society, 1949, 45, 894.

1824 work by Carnot. The German translation of the 1834 Clapeyron's work has been published in 1843 [7, 8], and thus attracted serious attention of the global research community.

Thereafter, Helmholtz was definitely triggering the discussion proper by frequently mentioning Carnot's results in his popular lectures. In 1854 in Königsberg he clearly stands behind what is well known as Clausius maxim: '*The Energy of the Universe remains constant, whereas Entropy of the Universe increases to its maximum*', and in all his public utterances praises the 'modifications Clausius introduced to Carnot's principle', while rejecting the idea of 'Energy Dissipation/Degradation' suggested by William Thomson (1st Baron Kelvin) and Peter Guthrie Tait after their careful analysis of Carnot's principle and Carnot's theorem.

To properly illustrate what we are discussing here, we place the English translations of all the relevant parts in Helmholtz's publications, see Appendices 1 and 2.

Helmholtz's 1847 report had attracted critical attention of Clausius already successfully dealing with his seminal research into the laws of thermodynamics [9, 10]. In 1853, Clausius had offered his immediate comments and questions in connection with Helmholtz's report [11], which triggered a professional discussion between both colleagues in 1854 [12, 13]. This discussion clearly demonstrates the very specific research direction in thermodynamics, which both peers were following. Of immediate interest for us here is the comment by a noticeable German (at the Baden's princedom) physicist Carl Alexander Holtzmann (1811–1865), who was performing thermodynamic studies in parallel to the peers [14]. His utterance to the Clausius' address reads as follows (cf. Appendix 6):

> *'...daß die geleistete Arbeit nicht die Wirkung der verbrauchten Wärme sein kann, sondern einer anderen Ursache entspringen muss; als solche wird sich wieder nur der Übergang von Wärme aus einem warmen zu einem kalten Körper bezeichnen lassen.'*
> *'… that the work performed cannot be the effect of the heat consumed but must stem from another cause; howbeit, as one such, only the transition of heat from a warm to a cold body could claim itself.'*

Therefore, Clausius was absolutely sincerely persuaded that the work performed is *the sole and direct effect of the heat consumed* by the machine. Holtzmann could but persuasively demonstrate that such a stance is not the proper standpoint, whereas the original suggestion by Carnot should be re-analyzed in much more detail. Noteworthy, we analyze the relevant discussion between Helmholtz and Clausius [11–13], as well as the deliberations of Helmholtz himself (Appendices 1, 2), and see that this comment by Holtzmann does pertain to Helmholtz as well.

It is clear then, where and how 'multiplicating the number of the Basic laws' might start. Now, the posers are: Why it could come this way? Were there some linguistic or mathematical difficulties?

To try answering this let us go to France. We open a book by an outstanding French mathematician Charles Auguste Briot (1817–1882) entitled '*Théorie mécanique de la chaleur*' and published in 1869, as a result of his careful investigation into Carnot's finding and its role in the then modern theory of heat. In Appendix 3 here, we place our English translation of the concluding paragraph in Briot's book, which is entitled 'Notes on the Carnot's theorem'. We immediately see that there were no linguistic and mathematical difficulties in this field, whereas Briot was expressing an opinion still readable even in the modern thermodynamics textbooks worldwide, namely the suggestion that Carnot was basing his considerations upon the old and unbearable theory, which was treating heat as a specific material body.

In reading this and immediately believing in it, we see no problem to share the entire standpoint of Clausius and Helmholtz: the scientific research was but progressing, and all the old, the unbearable ideas must be thrown away to the historical garbage, to free the space for the novel insights… Still, the story was not over at that point. We are continuing to stay in France to wait for some 50 years. That was just the time required to thoroughly re-analyze Carnot's legacy. This clearly demonstrates that the actual difficulty was by far not linguistic or mathematical: it was rather conceptual, philosophical, and methodological.

In Appendix 4, we place our partial English translation of the book by Louis-Marie-Joseph-Emmanuel Ariès (August 27, 1847, Le Carbet—February 24, 1923, Versailles), who was a higher military officer and thermodynamicist in France. Thus, he was to 100% a colleague of Sadi Carnot and undoubtedly had to bestow his collegial tribute. Indeed, the original title of his book is '*L'œuvre scientifique de Sadi Carnot: introduction à l'étude de la thermodynamique* (Payot, 1921)'.

Here we have presented the translation of a number of relevant paragraphs in the six chapters of this work. It contains Ariès' results of carefully reading the original 1824 work by Carnot and his handwritten notes published only in 1878. Lieutenant-colonel Ariès also analyzes the historical background of Carnot's work and the acceptance of the latter by modern research workers. Of particular interest for us here is also his analysis of Max Planck's stance in regard to Carnot's theorem.

We may summarize the actual situation around Carnot's legacy as follows.

1. Neither Carnot, nor Clapeyron have 'theoretically derived a number of laws' of whatever. There is only a *principle of Carnot* and a *theorem of Carnot*.
2. The Principle of Carnot has the following formulation:

> '*A heat machine, that is, a machine driven by heat, cannot produce work without the use of two heat sources having temperatures different from each other*.'

Indeed, Clausius could not grasp the actual significance of this principle at once, he needed some time to properly lump it. But, to our sincere regret, he could not have it, for 'Napoléon le Petit' has started in 1870 his war against Prussia, and a young patriot Clausius had to defend his Homeland. He was meanwhile severely wounded, as we know, thereafter he had also drastic family problems…

3. The Theorem of Carnot deals with the machines' efficiency and reads as follows:

> '*Even an ideal thermal machine using whatever working material, being deprived of any ubiquitous conventional resistances/obstacles/hindrances, following the idealized cyclic process comprised of two isothermal and two adiabatic fragments would anyway have maximum efficiency of about 25%*'.

We should never consider Carnot's theorem apart from Carnot's principle. Neither should we also deal with them both aside from the Energy Conservation principle. *Therefore, the unique Basic Law of thermodynamics is the Law of Energy Conservation and Transformation*. It does contain two aspects, which are but conceptually inseparable from each other.

The actual meaning of the Carnot's finding

There must ever be truly intrinsic, truly basic *resistances/obstacles/hindrances* to counteract any realistic process. To trigger the latter, we do need the proper driving/livening force. The pertinent energy form to provide us with such a force is Kinetic Energy to be spent for compensating the basic resistances/obstacles/hindrances for equilibrating them.

The very true result by Clausius, irrespective of his apparent difficulties with getting it, is *his theorem based upon the Carnot's theorem*, according to which the *entropy must anyway increase and finally reach its maximum*. Therefore, Clausius could anyway chase down the entropy, but he could not clarify its physical sense. Meanwhile, other colleagues could bridge the gap (see [3] for more details). The book by Ariès reveals that himself he was fully aware of what entropy actually is.

Howbeit, if we have kinetic energy enough to overcome the entropy maximum, that is, the maximum of *resistances/obstacles/hindrances*, our process must then reach its aim without fail. Consequently, the result must be the Degradation/Dissipation of the Kinetic Energy in favor of creating the least-usable form of Energy: the Heat. Carnot could in fact prove that Heat is just the least-usable energy form of their entire wealth. Since the *resistances/obstacles/hindrances* are ubiquitous just in accordance with the Newton's Third Basic Law (the Actions do anyway trigger the relevant Counteractions), we might physically consider the Entropy as a sum of the pertinent *resistances/obstacles/hindrances*.

Is the writer pioneering something herewith? No, because in Germany a physical chemist Horstmann, just a student of Clausius and Zeuner, had pioneered and was productively employing this idea. Meanwhile, in Great Britain, a physical chemist Liveing could productively embody the Kelvin-Tait ideas as for the Energy Dissipation/Degradation (cf. [3] for details).

Ariès' book teaches us that the Energy concept has Two Basic Sites, namely the *Energy Quantity* and *Energy Quality*. The Law of Energy Conservation and Transformation does take these both Basic Sides of Energy under one umbrella.

4. Carnot had never been a proponent of the material theory of heat. *His actual idea was to theoretically analyze the conceptual roots of why the Perpetuum Mobile is impossible*, and he could suggest the truly ingenious solution to this problem.
5. Remarkable is also the over-all international stance in regard to Carnot's legacy. Commander Ariès could not only tell us the story about how all the things looked like in his time but provide us with the careful professional analysis of the then situation as well.

The difficulties with grasping Carnot's ideas could lead, e.g., to the emergence of Maxwell's demon, pursuing which has no truly realistic physical sense apart from striving for the invention of *Perpetuum Mobile*.

Of definite interest is a unique analysis presented by Ariès as for Max Planck's stance in regard to thermodynamics. Max Planck had already got his Nobel Prize in 1918; so coming to grips with him did become 'politically incorrect'. Thus, Ariès could provide us with the fully unbiased picture.

First of all, we learn that Max Planck was not recognizing the actual significance of the Carnot's principle. Ariès clearly shows that Max Planck was well aware of the notion of *Energy Quantity* but to 100% rejected the notion of *Energy Quality*.

This is good to know, because it might shed light on the poser of how Planck could come to the idea of the Energy Quantum. As he considered the *quantitative* side of the Energy notion whereas rejecting its *qualitative* aspect, he dealt with the Energy notion from the purely materialistic viewpoint. Along with this, he could but evaluate Boltzmann's famous $S = log\ (W)$ conjecture as a nice opportunity to cope with all the other aspects of the Energy notion by enforcing their statistical interpretation. It is just this way that *he could successfully manage to treat the entire pool of the entropic effects implicitly*.

Now, we do know well: the Energy Quantum picture is dispensable, because all the formulas it helps produce could instead be inferable starting from Gibbs' results without even taking this hypothesis into account (Simon Ratnowsky could just show this, cf. [4]): this suggests that the ideas forming the basis of quantum mechanics are basically voluntary and metaphysical. Howbeit, the contribution by Einstein, who could show the way to theoretically get rid of '*uneasy*' effects just by declaring them '*relativistic*', plus, *first of all*, the contributions by de Broglie, Schrödinger, Heisenberg, and a truly international team of their numerous followers, not to forget the actual compatriot of Simon Ratnowsky – Yakov Ilyich Frenkel – among them, could ultimately help render Quantum Mechanics a valid and throughout useful, seminal physical theory.

Regarding the Quantum Mechanics, the role of the 'Equilibrium Thermodynamics' and 'Statistical Mechanics' was and is mainly supportive: The latter both are in effect not standalone.

This urges us to work on recovering the different (*the actual*) thermodynamics – thermodynamics of Carnot or, in other terms, Energetics, and to make use of its productivity by properly deploying such truly powerful, tried-and-true computer-based tools derivable from the Quantum Mechanics as *Quantum Chemistry* and *Classical Molecular Mechanics* – in their entire functional spectrum.

But is it possible to treat Carnot's principle within the frame of statistical mechanics?

Such a poser arises quite naturally if we would like to consistently pursue the above recommendation. The answer is positive. To learn why, we would need to come back to Germany in the very times of Helmholtz and Clausius.

It is but throughout possible to analyze the actual Helmholtz and Clausius' seminal ideas carefully and thoroughly – to draw interesting and important conclusions.

Indeed, when recalling the works by Clapeyron and Carnot for the first time in 1847, Helmholtz could correctly grasp their main point: They did have to do with the Conservation of *Vis Viva*, that is, of the *Livening/Driving Force* – or *Kinetic Energy*.

What neither Helmholtz, nor Clausius were but dealing with hereafter was to analyze in detail the actual modalities of the *Vis Viva Conservation*.

This work has been carefully and thoroughly performed by Franz Ernst Neumann (1798–1895), a prominent German mineralogist, physicist, and mathematician. His personal story is very similar to that of Clausius, for Neumann, a young Prussian patriot, had to defend his Homeland that time but from Napoléon le 1er. In 1815 he interrupted his studies at the University of Berlin to serve as a volunteer in the '*Hundred Days against Napoléon*' and was truly severely wounded during the Battle of Ligny. He could nonetheless combine all his forces not only to complete his studies, but also to follow an outstanding academic career. Specifically, he was a professor of mineralogy and physics at the University of Königsberg from 1828 till his retirement in 1876.

Of undoubted thermodynamic relevance among his numerous contributions to diverse fields of physics is his law, now well known as *Neumann's Law*: *The molecular heat of a compound is equal to the sum of the atomic heats of its constituents*.

His theoretical results concerning the *Vis Viva Conservation* are much-much less known, although they could still be published after his retirement in the 1883 book entitled '*Einleitung in die theoretische Physik. Vorlesungen, gehalten an der Universität zu Königsberg von Dr. Franz Ernst Neumann* '. This seminal book has been edited by one of the numerous Neumann's students, a physical chemist Carl Johannes Wilhelm Pape (1836–1906).

Appendix 5 gives our authorized English translation of the central paragraph, § 48, in Chapter IV of Neumann's book. The Chapter's title: '*The Law of Livening Force Conservation*'.

Noteworthy, this Chapter contains i. a. § 46 (*Conditions for a System of Mass Particles. A Function of Force*) and § 47 (*Examination of the Cases, in Which the Law of the Livening Force Conservation Does Not Apply and in Which it Applies. Consideration of a Mass Particle*) as well, where Neumann is very carefully and thoroughly introducing the necessary mathematical notations and approaches.

Of immense importance for our present consideration is the presence of physically motivated sub-paragraphs in § 47 dealing with the time dependence of forces, with the forces acting as obstacles, hindrances, or resistances and with frictional forces in particular. Neumann could prove and had stressed the sheer inapplicability of the Livening Force Conservation Law in the presence of the latter circumstances.

Neumann's results could be summarized as follows:

1. Kinetic Energy or the Livening Force in a multiparticle system can be conserved if and only if at the same time the entire system attains the same absolute starting position, with its subsystems having these same relative starting positions, given there is the simultaneous action of external and internal forces.

This is but nearly the case of Carnot's ideal cyclic machine. Step by step, Neumann leads us hence to understanding, what might be the realistic physical source of the

Carnot's theorem. Yet there is still one more important point to the story:

2. Occasional kinks in the particles' trajectories must lead to the ultimate loss in the over-all kinetic energy of the system under study. This is the possible physical sense of Carnot's theorem.

Nowadays, the above may be of ultimate interest in interpreting the trajectories of the full-atomic molecular-dynamical simulations. Indeed, we might analyze the atomic velocities in hoping to reveal the Neumann's trajectory kinks. The difference between the velocities before and after such trajectory kinks should give the lost kinetic energy, that is, the entropy times the temperature of the simulation. The sum of such contributions along the productive trajectory would give the total energy degradation in the system. By inspecting, which degrees of freedom of which residues along the simulated macromolecular trajectory do experience such kinks, it is possible to learn, which parts of the simulated macromolecule do take part in the entropic effects.

This could be a useful supplement to the exploratory factor analysis of the pairwise correlations among the normal coordinates along the simulated macromolecular trajectory in terms of the atomic coordinates, which also helps reveal the entropic effects in question (see [4] for further details).

Can we expect realistic and useful results from such an approach?

The analysis of the available literature enables us to give the largely positive answer. Indeed, the trajectory kinks of the type we discuss here have been observed [15, 16], although it is not immediately clear for the present, how we might distinguish among the apparent purely numerical drawbacks and incidents interpretable in terms of the realistic effects. This definitely requires further analyses, but such an approach looks promising anyway.

For example, we might try performing the exploratory factor analysis of the pairwise correlations between the atomic impulses (kinetic energy) along the trajectory, in addition to that for the normal atomic coordinates (potential energy). Thus, we hope to arrive at the set of intrinsic factors inherent in the impulses' correlations, which do go beyond the noise produced numerically and/or otherwise.

Adverse events/side effects: 'energy, entropy, hysteria'

Above we do have approached an interesting topic, which has started to be hotly debatable right after its emergence (cf. Appendix 6 for details) and is *still remaining largely emotional*, rather than being just a subject of the conventional scientific investigation…

Why do we ever get such a strange, such a stubborn feeling?

This is a result of reading fiction, and here we do bring some relevant examples [17, 18].

The work [17] is a typical science fiction piece, we cite:

> *'Peter Goodman is a brilliant scientist with a great job at NASA, but his life is plagued by the law of entropy – the fact that everything in the universe, including Peter's marriage and moral character, gets gradually worse over time. Things get even more complicated when alien invaders from another galaxy land in Washington, D.C., seeking an ultimate solution for death, decay, and degeneration, even at the cost of human life. Peter has a chance to help the aliens and save his people, but how can he be expected to solve the universe's problems when he can't even get his own life in line? Peter doesn't know, but if he can't find a solution, then the people of Earth will have a very high price to pay'…*

The zest of the above does sound as follows: *The scientists are fighting with some enigmatic difficulties all of us experience through some mischievous aliens, whatever they might come from.*

To the writer's mind, such a standpoint is disastrous, for if we do have some difficulties, to correctly oppose the latter we ought to look around, to look inside ourselves, without trying to fetch some '*aliens*' responsible for our mishaps, as well as some '*scientists*' who would be helpful in overcoming the consequences of our mishaps…

The work [18] does belong basically to this same genre as the above; it is written in German and authored (most probably) by some of the '*helpful scientists*', who is adopting the pseudonym just to share his/her '*thorough and detailed scientific analysis*' (500 pages!) of the very penetrating disaster, which is stubbornly surrounding us in our everyday lives. The author is sermonizing a '*cool pessimism*', but why pessimism? '*We have to be pessimists*' simply because professional natural scientists (having all the necessary experience to be attached to hard sciences / professions) are mostly not well suited for political business, and because they do know this self-critically so that only few of them do finally decide to take the '*political*' path…

…Sure, everything looks hopeless, vain, and futile… But what is the actual reason for such a desperate situation? To the writer's mind this pertains to the extremely stubborn vividity of the notorious Clausius maxim – the Great Natural-Scientific Revolution at the end of the XIX-eth through the beginning of the XX-eth centuries did hit and thrust both the notorious maxim and the insatiable strive to invent *Perpetuum Mobile* – but could apparently have never overcome these artefacts…

Why the Great Revolution could not kill the latter stubborn 'aliens'?

Because Quantum Mechanics based upon the Statistical Mechanics and, ultimately, upon the Equilibrium Thermodynamics could not suggest the EXPLICIT solution to the problem… This is why *Entropy* is remaining *The Implicit and Perfidious Enigma of All the Times and All the Peoples*…

To observe the proof of such a pessimistic conclusion please confer all the thermodynamics textbooks in all the languages upon Earth (here we wish to place only several English references for the reason of the paper economy: [19–27]). After reading the cited works as well as observing the impressive geography of their publishing the writer does have absolutely no doubt that distributing the fiction likewise [17, 18] would be throughout successful, if the colleagues would never force themselves to critically re-read their writings, and never strive for revising and duly amending them…

It is throughout important to recognize that the actual history of thermodynamics is in effect truly long – and therefore has never been rectilinear – due to the wars, social revolutions, and economic depressions.

The correctness of the above conclusion is observable in studying the relevant literature (e.g., [28–32]), and the personal destinies of the authors:

1. The author of [28], Eduard Wilhelm Leonhard Justi (1904–1986), a German physicist and pedagogue, a student of Albert Einstein, Max von Laue, Max Planck, and Erwin Schrödinger, a patriot, had to continue his professional work, despite the dreadful Nazi encroachment onto his Homeland while having most probably to suppress his negative emotions due to the latter fact.
2. Now, the author of [30–32] Ernst Pascual Jordan (1902–1980), an outstanding German theoretical physicist and politician, was one of the undoubted Peers of the then revolutionary Quantum Mechanics, which he was considering an undoubted '*Vorsprung*' (in German, *An Advance, A Forward Push*) in Physics [31, 32]. Howbeit, his clear acceptance of the Nazi usurpation (he was an official member of NSDAP, and '*Sturmabteilung*') demonstrates that he could never feel the actual difference between the true '*Advance*' and '*Impingement*' or even '*Intrusion/Invasion*'… This is just what might become clear, if we do consider Jordan's efforts in the '*Quantum Biology*' that is, a field he had invented himself and was stubbornly trying to anyway advance [33]…

3 Whatever the actual degree of our personal impassibility and/or numbness our fates are always especial… Indeed, Karl Ludwig von Bertalanffy (1901–1972) a renowned Austrian theoretical biologist and system theorist, was both an enthusiast of Jordan's ideas [34], and the follower of similar lines of thoughts [35, 36], while being an official member of NSDAP. Nonetheless, he was never completely destroyed by *Denazification* – likewise Jordan himself – while having duly recognized the failure of Nazism…

4. Meanwhile, among the authors of a truly interesting work on the theoretical biology [37], which we might now view as a kind of moving along the Jordan's lines of thoughts [38], there have been but no sincere adepts of any kind of political absolutism either Nazism or Stalinism. Specifically, Nikolai Vladimirovich Timoféeff-Ressovsky (Николай Владимирович Тимофеев-Ресовский, 1900–1981), a renowned Russian/Soviet geneticist, who was – *inter alia* – a fan of both Bertalanffy [36] and Jordan [38] ideas, *had to escape from the USSR* to Germany, where he could work from 1925 to 1945, *without but any political contact and/or conflict with Nazis.* Still, Stalinists have seized him in 1945, forcefully repatriated, and persecuted. On the other hand, Friedrich Möglich (1902–1957), a German theoretical physicist, was initially an official member of NSDAP. Still, thereafter Gestapo had stubbornly tried to persecute him, formally for his alleged '*Devisenvergehen und Rassenschande*', which, in fact, was just a result of his romance with a Jewish girl… But after spending some very difficult time abroad, he could come back home, and even get some job under assistance of his teacher, Max von Laue, to start decidedly working against Nazis in fact, likewise Robert Wilhelm Hermann Rompe (1905–1993), a fine German physicist, specialist in engineering optics, spectroscopy. Rompe was but an official member of the German Communist Party, an active agent of the Soviet Military Intelligence Service (GRU) – and such activities of Rompe and Möglich could finally ensure their positions at the Humboldt University of Berlin i.e., in the German Democratic Republic, which has become just a Stalinist enclave after 1945. Thus, in parallel to all these stories, the destiny of Heino Zeise (1902–1954), a fine German physical chemist, a student of Walther Nernst (the topic of Zeise's PhD thesis has been '*molecular mechanisms of gas adsorption*' [39]), the author of an interesting thermodynamic book [29], has been but the toughest one. Specifically, while taking part in no political activity of any kind, Zeise, being a true professional and a patriot of his country, was, from 1939 on, duly & properly working at the *Deutsche Versuchsanstalt für Luftfahrt* in Berlin-Adlershof. Howbeit, Stalinists had unexpectedly forced him to move to the USSR in 1946, where he had to spend some 7 years… After his coming back home in 1953, he had been extremely ill – and could thus not really work anymore…

Among the colleagues mentioned above, that was only Dr. Zeise, who was truly stubbornly trying to fetch the actual interconnection between *Thermodynamics* and *Quantum Mechanics*…

For our present discussion, it is important to stress that the *Basic Side Effect* of the Great Revolution in the Natural Science, which could result in emergence of Quantum Mechanics, ought to be the *stubborn tendency* of *Bidding Farewell to Reality* (cf., e.g., [40]). It is thus our holy devoir to recognize the negative trends likewise those presented and analyzed in [17, 18, 40], just to protect our holy right to perform the proper scientific research work, like that presented in [41, 42], for example…

Conclusions

1. There is only one Fundamental Basic Law of Thermodynamics: *The Law of Energy Conservation and Transformation*.
2. This law introduces two important sides of the Energy notion: The *Quantitative* and the *Qualitative* ones, respectively.
3. The physical sense of the *Entropy* notion consists in assigning the entropic effects to the ubiquitous resistances/obstacles/hindrances of any realistic kind arising in the natural course of realistic processes.
4. Increasing entropy – or producing heat – corresponds to the energy dissipation, or energy degradation, with the heat being the least-useful energy form.
5. Provided the process' Kinetic Energy the driving force enough to compensate or equilibrate the maximum of entropic effects, the process was successful.
6. The so-called 'Third Basic Law of Thermodynamics' is in effect the consequence of Carnot's principle: Indeed, the entropy does mathematically go to zero at the zero absolute temperature (Linhart's result). Physically, the entropy may be zero if and only if the driving force is equal to zero. Otherwise, along with the driving force gain, entropy increases and anyway reaches its maximum. As practically achieving the absolute temperature zero must require a non-zero driving force, the physical entropy may never come to zero (cf. [3] for further details).
7. The so-called Zeroth Basic Law is just '*Much Ado about Nothing*' (trying to invent some physics out of pure mathematics; cf. [3] for further details).
8. Analysis of Kinetic Energy (impulse) fluctuations along the simulated full-atomic molecular-dynamic trajectories might deliver information concerning the relevant entropic effects, but one must know first of all, how to separate the reasonable effects from the noise due to numerical drawbacks and/or other sources.
9. Exploratory factor analysis might definitely help distinguishing among the noises of whatever origin and the realistically interpretable effects.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00706-021-02803-w.

References

1. Atkins P (2010) The laws of thermodynamics. A very short introduction. Oxford University Press, Oxford
2. Wyatt PAH (1971) The molecular basis of entropy and chemical equilibrium. Monographs for teachers, number 19. Royal Society of Chemistry, London
3. Starikov EB (2019) A different thermodynamics and its true heroes. Pan Stanford Publishing, Singapore
4. Starikov EB, Nordén B, Tanaka S (eds) (2020) Entropy-enthalpy compensation: finding a methodological common denominator through probability, statistics, physics. Jenny Stanford Publishing, Singapore
5. Brush SG (1965) Kinetic theory, vol 1. The nature of gases and of heat. Pergamon Press, Oxford
6. Brush SG, ter Haar D (1966) Kinetic theory, vol 2. Irreversible processes. Pergamon Press, Oxford
7. Clapeyron E (1843) Ann Phys 135:446
8. Clapeyron E (1843) Ann Phys 135:566
9. Clausius R (1850) Ann Phys 155:368
10. Clausius R (1850) Ann Phys 155:500
11. Clausius R (1853) Ann Phys 165:568
12. von Helmholtz H (1854) Ann Phys 167:241
13. Clausius R (1854) Ann Phys 167:601
14. Holtzmann C (1851) Ann Phys 158:445
15. Zhou HB, Wang L (1996) J Phys Chem 100:8101
16. Lahiri A, Nilsson L (1999) Chem Phys Lett 311:459
17. Harris SN (2010) The entropy enigma. Create space independent publishing platform. San Bernardino, CA, USA, 30 September 2013
18. Schwarz AT (2012) Energie, entropie und hysterie. Der erste populär-wissenschaftliche Rastgeber für coole Pessimisten. Litereareon/Herbert Utz Verlag GmbH, München
19. Ambegaokar V (2003) Reasoning about luck. Probability and its uses in physics. Cambridge University Press, Cambridge
20. Roy BN (2005) Fundamentals of classical and statistical thermodynamics. Wiley Student Edition for Bangladesh, Myanmar, India, Indonesia, Nepal, Pakistan, Philippines, Sri Lanka, Vietnam
21. Awode MR (2005) Nonequilibrium thermodynamics. irreversible thermodynamics of physico-chemical and biological processes. Kiran Nangia Dattsons Publishing, Nagpur
22. Schroeder DV (2007) An introduction to thermal physics. Pearson Education/Dorling, Kindersley
23. Mandl F (2010) Statistical physics. John Wiley and Sons, Chichester
24. Swendsen RH (2012) An introduction to statistical mechanics and thermodynamics. Oxford University Press, Oxford
25. Elliott RJ, Lira CT (2012) Introductory chemical engineering thermodynamics. Pearson Education International, Upper Saddle River, NJ, Boston, Indianapolis, San Francisco, New York, Toronto, Montreal, London, Munich, Paris, Madrid, Capetown, Sydney, Tokyo, Singapore, Mexico City

26. Jacobs P (2013) Thermodynamics. Imperial College Press, London
27. Agarwal BK, Eisner M (2013) Statistical mechanics. New Age International Publishers/Ajit Printders/Delhi, Delhi
28. Justi E (1938) Spezifische wärme, enthalpie, entropie und dissoziation technischer gase. Verlag von Julius Springer, Berlin
29. Zeise H (1944) Thermodynamik auf den Grundlagen der Quantentheorie, Quantenstatistik und Spektroskopie, Erster Band. Grundlagen aus den Gebieten der klassischen Thermodynamik, klassischen Mechanik, klassischen Statistik Quantenmechanik und Quantenstatistik. Verlag von S. Hirzel, Leipzig
30. Jordan P (1944) Statistische Mechanik auf Quantentheoretischer Grundlage. Verlag Friedrich Vieweg & Sohn, Braunschweig
31. Jordan P (1947) Das Bild der Modernen Physik. Stromverlag Hamburg-Bergedorf, Hamburg
32. Jordan P (1949) Physik im Vordringen. Springer Fachmedien, Wiesbaden
33. Beyler RH (1996) Isis 87:248
34. von Bertalanffy L (1943) Naturwissenschaften 31:23
35. von Bertalanffy L (1940) Naturwissenschaften 28:521
36. von Bertalanffy L (1944) Naturwissenschaften 32:26
37. Möglich F, Rompe R, Timoféeff-Ressovsky NW (1944) Naturwissenschaften 32:316
38. Jordan P (1938) Naturwissenschaften 26:537
39. Zeise H (1928) Z Phys Chem 136U:385
40. Baggott J (2014) Farewell to reality. How modern physics has betrayed the search for scientific truth. Pegasus Books, New York
41. Franchi S, Güzeldere G (eds) (2005) Mechanical bodies, computational minds. Artificial intelligence from automata to cyborgs. MIT Press, Cambridge
42. Khonsari MM, Amiri M (2013) Introduction to thermodynamics of mechanical fatigue. CRC Press, Taylor & Francis Group, Boca Raton