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Clausius and Darwin Can Both Be Right

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Abstract: The apparent paradox represented by the second law's future of decay and the evolution of living structures in nature has been introduced. The second law in its historic-conventional form has been discussed. The corrected version of this law in terms of new research on the foundations of classical thermodynamics has been discussed. Finally a resolution of the apparent paradox has been proposed in the light of these newer advances.

Keywords: Entropy, Evolution, Paradox, Carnot Engine, Second Law

1. Introduction

The apparent paradox at the heart of classical thermodynamics is the *collapse into disorder* advocated by the second law of thermodynamics and nature's incessant success in turning chaos into order, as for instance, in the self-organization of a living cell and its subsequent evolution into a complete organism [1–3]. Roger Caillois gave expression to this feeling of failure of the thermodynamic method with the following words: "Clausius and Darwin cannot both be right" [4–6]. This apparent conundrum has led few to believe in the existence of some very special principles governing the origin and evolution of life [7–9] while others have speculated [10, 11], and even discussed [12–14], about the existence of some hitherto not so well known laws governing the thermodynamics of open systems. That life is a thermodynamic phenomenon is now already a well established concept [15, 16]. Therefore the origin and evolution of life should also be best understood through the use of thermodynamic principles.

Thermodynamically, the evolution of living matter is described by postulating the validity of the *negentropy principle* [17–19]. According to this, the evolution of biological systems occurs in the direction in which the structure becomes more complex [20, 21]. Nevertheless, a clear cut correlation between negentropy and order is yet to be found [22]. However, recent research on the foundations of classical thermodynamics suggests that self-organizing phenomena (order) could be accommodated within the realm of this science and that too without one having to invoke a quantitative correlation between negentropy and order [23–25]. The new approach also points out that no new principles are needed to bring self-organizing phenomena, like the evolution of complex biological structures such as DNA and the cells, into the realm of thermodynamics. All we need do is recognize a basic flaw in the conventional formulation of the second law of thermodynamics.

2. Conventional Second Law; the Reversible Engine

The most common and historically precise way of introducing the *second law of thermo-dynamics* is to imagine a reversible engine absorbing a certain quantity of heat Q_h from a hot thermal reservoir at temperature T_h, converting a part Q of this absorbed heat into work W and discarding the remaining portion Q_c to a cold thermal reservoir at temperature T_c [26–32]. For this kind of reversible cyclical transformation, known as the Carnot reversible engine (cf. Fig. 1) the following results hold:

$$Q_h - Q_c = Q \tag{1}$$

$$Q = W \tag{2}$$

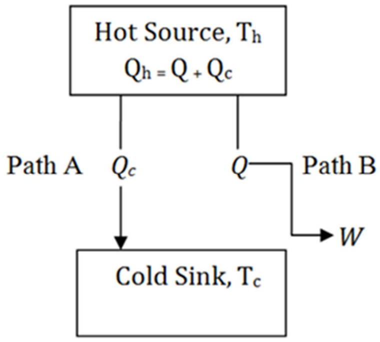

Figure 1. *Carnot reversible engine.*

This traditional approach to the second law associates a zero entropy change to the reversible production of work out of heat [33]. Thus, if dS denotes the entropy change, then for the reversible production of work W out of heat Q we write:

$$\mathrm{dS}(\mathrm{Q} \rightarrow \mathrm{W}) = 0 \tag{3}$$

The justification for above assumption rests on the notion that work done can always be related to the raising (or lowering) of a weight somewhere in the surroundings [2] and that process is, by its nature, reversible and isentropic [34]. Then as per Clausius' theorem [4]:

The algebraic sum of all the transformations which occur in a cyclical process must always be positive or in the limit equal to zero.

For the reversible heat engine under consideration this means:

$$\mathrm{dS}_{\mathrm{A,rev}} + \mathrm{dS}_{\mathrm{B,rev}} = 0 \tag{4}$$

It is on the basis of above kind of analysis that Rudolf Clausius made the following broad generalization, now known as the second law of thermodynamics:

The entropy of the universe is continuously increasing as a result of every spontaneous (or irreversible) process.

Since entropy is also taken as a measure of the disorder or randomness in the system, by this he meant that the disorder or randomness of the universe was increasing with time. In fact it was Clausius who originally introduced [35] the term *entropy* (meaning transformation) which according to him is a measure of the thermal energy of a system per unit temperature that is unavailable for doing work. Mathematically, according to Clausius:

$$\mathrm{dS} = \frac{\mathrm{dQ_{rev}}}{\mathrm{T}} \tag{5}$$

Equation (5) is commonly taken as the thermodynamic definition of entropy. Equation (4), therefore, expresses the second law of thermodynamics as applied to a reversible process and for an irreversible process as per Clausius's postulate:

$$\mathrm{dS_{irr}} > 0 \tag{6}$$

The assertion that $dS_{irr} = 0$ is apparently incompatible with the second law and therefore would represent a counter argument to it. As will be shown below this equality is actually a correction that needs to be applied to the Clausius formulation of second law and hence, quantitatively, refute the paradox mentioned in the beginning.

3. Corrected Second Law

3.1. The Irreversible Engine

In order to derive the conclusion $dS_{irr} = 0$ let us consider a situation in which the work *W* generated by the reversible Carnot engine(cf. Fig. 1**)** is irreversibly degraded, via some frictional mechanism, into an equivalent amount of heat *Q* at the temperature T_c of the cold reservoir (cf. Fig. 2 below).

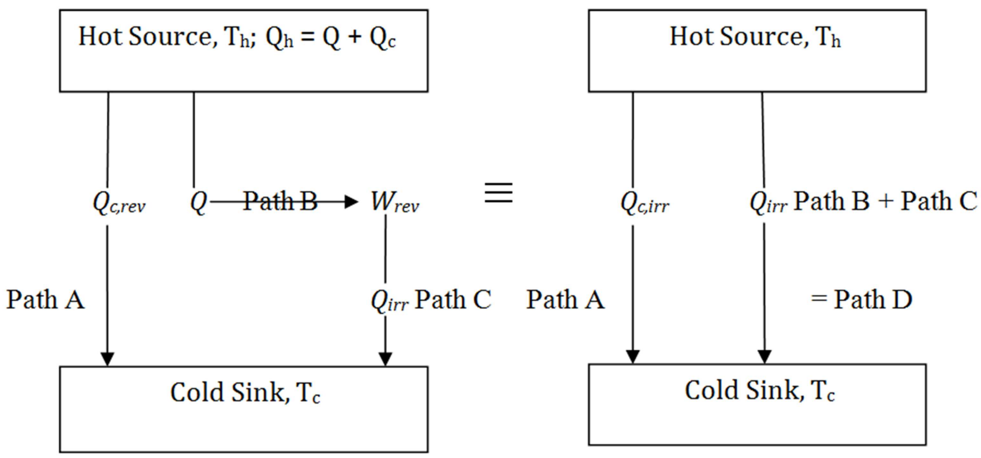

Figure 2. *Reversible production followed by irreversible degradation.*

The very fact that the reversible work in above transformation has been irreversibly degraded into heat makes the whole process irreversible. This has been indicated on the right-hand side of the diagram in Figure 2 by attaching the label "*irr*" to the respective energy changes involved. The physical reason for this shift is the fact that the reversion of *Q* or Q_c or both back to the hot source from the cold sink demands the expenditure of work that we don't have available here.

The entropy change for above kind of transformation will be given by

$$dS_{irr,engine} = dS_{A,irr} + dS_{D,irr} = dS_{A,rev} + dS_{B,rev} + dS_{C,irr} = 0 + 0 + \frac{W}{T_c} = \frac{Q}{T_c} \quad (7)$$

Where in writing the result expressed by equation (7) we have made use of equations (2) and (4) and the fact that an irreversible degradation of an amount of work δW into heat at some temperature T will result in an entropy increase of magnitude δW/T [23]. This fact is itself a consequence of an observed asymmetry [31] in nature whereby it is possible to convert all of the work irreversibly into heat but not all of the heat into work; even reversibly. Since the combination of transformations $[Q(T_h) \rightarrow W]_{rev}$ and $[W \rightarrow Q(T_c)]_{irr}$ on the left-hand side has been replaced by the single transformation $[Q(T_h) \rightarrow Q(T_c)]_{irr}$ on the right-hand side, one can deduce from equation (7) that:

$$dS_{D,irr} = dS_{B,rev} + dS_{c,irr} = 0 + \frac{W}{T_c} = \frac{W}{T_c} = \frac{Q}{T_c} \quad (8)$$

Or more concisely:

$$dS_{D,irr} = \frac{W}{T_c} = \frac{Q}{T_c} \quad (9)$$

Comparing (7) and (9) we can therefore write:

$$dS_{irr,engine} = dS_{D,irr} = \frac{W}{T_c} = \frac{Q}{T_c} \quad (10)$$

3.2. The Correction

Equation (10) is a very interesting result. It shows that the entropy change for above irreversible process (engine) is solely a result of the transfer of an amount of heat *Q* from the hot to the cold reservoir or in other words due to the transformation $[Q(T_h) \rightarrow Q(T_c)]_{irr}$. But if this is so then the other transformation involved in the process, that is, the irreversible transfer of Q_c from the hot source to the cold sink, represented as $[Q_c(T_h) \rightarrow Q_c(T_c)]_{irr}$, takes place at constant entropy:

$$dS_{A,irr} = 0 \quad (11)$$

The transformation represented by equation (11) is reversible on account of its entropy change but irreversible because of the impossibility of transferring Q_c back to the hot source without utilizing some external agency. We seem to have stumbled upon some kind of a thermodynamic impasse [23] where the only option left to us, in order to make any further progress (that is, the only option for the constant entropy criterion expressed by equation (11) to remain valid) is for heat Q to flow, in some mysterious way, on its own (unassisted by some external agency) from the cold to the hot reservoir. The observation that such a transfer is denied by experience tells us that the only way to save the situation is to abandon the notion that thermodynamically irreversible processes are always accompanied by an increase of entropy of the universe. This in other words means that constant entropies are not uniquely limited to reversible processes only.

4. Discussion

The above conclusions, which were reached by an unambiguous thermodynamic analysis of the problem, can have far reaching consequences. An immediate corollary for us here is the observation, based on above analysis, that the collapse into disorder, commonly believed as the hallmark of the second law, is a misleading conclusion from the theory; because as per above analysis it is perfectly sensible to write $dS_{irr} = 0$. A correct way to express the second law would therefore be to say that:

The entropy of the universe may increase as a result of some spontaneous (or irreversible) process.

But why did Clausius get it amiss? The answer is that perhaps he performed his Carnot analysis by considering an idealized (reversible) process only, without introducing some irreversibility into the problem. As per his incomplete analysis Clausius deduced that the entropy of the universe remains constant in a reversible process even if the process involved the creation of certain amount of work. Then, based on this deduction, he made the bold generalization that since in a spontaneous (or irreversible) process the entropy cannot decrease so it must increase [35]. But we showed above that as soon as some irreversibility is introduced into the model the supposed equivalence between constant entropy criterion and reversibility gets nullified. So what does all this mean for our paradox mentioned in the beginning? It means that since the entropy of the system does not always tend to a maximum, that is, things do not always go up the slope of disorder the paradox mentioned in the beginning is not a valid one. There is no reason, therefore, to accept that entropy and evolution are antagonistic to each other. Clausius and Darwin are both firmly footed when it comes to the validity of the two of the great doctrines of science: *entropy* and *evolution*. Since entropy is fundamentally a measure of dispersal of energy at the microscopic level [36] this connection between entropy and evolution is also of fundamental importance for any biological theory for the origin and evolution of life. Our conclusion above, although not a new one as the same has been reached in other indirect ways also [3, 6, 11] is certainly better grounded, however.

5. Conclusion

Inclusion of irreversibility, in the form of irreversible degradation of work into heat via some frictional mechanism, in the operation of Carnot reversible engine leads to the refutation of the apparent paradox represented by the second law's future of decay and the local ordering of structures in nature, as for instance in the origin and evolution of life. The results obtained show that Entropy and Evolution are not antagonistic to each other and Clausius's version of the second law needs to be corrected to bring it in line with the occurrence of self organizing phenomena (order) in nature.

Conflict of Interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be considered as a potential conflict of interest.

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References

[1] Thims, L. Second Law and Three Evolution Paradoxes: Life, Evolve and Soul. *J. Hum. Therm.* 2015, 10(1), 1-14.

[2] Atkins, P. W.; de Paula, J. *Physical Chemistry;* 8th ed.; New York, NY: W. H. Freeman and Company, 2006; pp. 78.

[3] Atkins, P. W.; de Paula, J. *Physical Chemistry for the Life Sciences;* Oxford, UK: Oxford University Press, 2008; pp. 93.

[4] Clausius, R. *The Mechanical Theory of Heat;* London, UK: Macmillan and Co., 1879.

[5] Darwin, C. R. *On the Origin of Species by Means of Natural Selection,* ed. J. Murray, London, 1859.

[6] Prigogine, I. *From Being to Becoming: Time and Complexity in the physical sciences;* New York, NY: W. H. Freeman and Company, 1980; pp. 84.

[7] Waldrop, M. M. *Complexity: The emerging science at the edge of order and chaos;* New York, NY: Touchstone, 1992; pp. 168.

[8] Demetrius, L. Thermodynamics and evolution. *J. Theor. Biol.* 2000, 206, 1–16.

[9] Pross, A. Toward a general theory of evolution: Extending Darwinian Theory to inanimate matter. *Jour. Syst. Chem.* 2011, 2, 1–14.

[10] Kauffman, S. *Investigations;* New York, NY: Oxford University Press, 2004; pp. 2.

[11] Prigogine, I.; Nicolis, G.; Babloyantz, A. Thermodynamics of evolution. *Phy. Today* 1972, 25, 23–28.

[12] Onsager, L. Reciprocal relations in irreversible processes. II. *Phy. Rev.* 1931, 38, 2265–2279.

[13] Kleidon, A.; Malhi, Y.; Cox, P. M. Maximum entropy production in environmental and ecological systems. *Proc. R. Soc. Lond. B.* 2010, 365, 1297–1302.

[14] Morel, R. E.; Fleck, G. A fourth law of thermodynamics. *Chemistry. 2006*, 15, 305–310.

[15] Levlock, J. E. A physical basis for life detection experiments. *Nature* 1965, 207, 568–570.

[16] Skene, K. R. Life's a Gas: A Thermodynamic Theory of Biological Evolution. *Entropy* 2015, 17, 5522–5548.

[17] Schrodinger, E. *What Is Life? With Mind and Matter and Autobiographical Sketches;* Cambridge University Press: Cambridge, UK, 1992; pp. 70–73.

[18] Brillouin, L. Negentropy Principle of Information. *J. of App. Phy*. 1953, 24(9), 1152–1163.

[19] Ulanowicz, R. E.; Hannon, B. M. Life and the Production of Entropy. *Proc. of the Roy. Soc. of Lond. B.* 1987, 232(1267), 181–192.

[20] Ziehe, M.; Demetrius, L. Directionality Theory: An Empirical Study of an Entropic principle in Life-History Evolution. *Proc. of the Roy. Soc. of Lond. B.* 2005, 272(1568), 1185–1194.

[21] Prigogine, I. Time, Structure and Fluctuations. *Science.* 1978, 201(4358), 777–7 85.

[22] del Castillo, L. P.; Vera-Cruz, P. Thermodynamic Formulation of Living Systems and Their Evolution. *J. Mod. Phy.* 2011, 2, 379–391.

[23] Iniguez, J. C. An unusually efficient coupling of Carnot engines. *Apeiron*. 2010, 17(2), 150-172.

[24] Iniguez, J. C. A Thermodynamic Impasse: A constant entropy irreversible process. *Phy. Chem.: An Indian Jour.* 2011, 6(3), 125–130.

[25] Iniguez, J. C. *A Critical Study of the Law of Increasing Entropy;* Conshohocken, PA: Infinity Publishing Co., 2012.

[26] Carnot, S. *Réflexionssur la Puissance Motrice du Feuetsur les Machines Propres a Développer Cette Puissance*; Chez Bachelier: Paris, France, 1824.

[27] Zemansky, M. W. *Heat and Thermodynamics;* 5th ed.; New York, NY: McGraw-Hill Book Company, 1968; pp. 177.

[28] Engel, T; Reid, P. *Physical Chemistry;* Pearson Education, Inc. 2006, pp. 80–85.

[29] Haynie, D. T. *Biological Thermodynamics*; Cambridge University Press: Cambridge, UK, 2008; pp. 61.

[30] Ball, D. W. *Physical Chemistry*; Brooks/Cole–Thomson Learning, CA: USA, 2003; pp. 68–75.

[31] Levine, I. N. *Physical Chemistry;* 6th ed.; McGraw-Hill Companies, Inc, 2009; pp. 77–87.

[32] Atkins, P. W. *Four Laws That Drive the Universe;* Oxford University Press Inc: New York, 2007; pp. 47–78.

[33] Pitzer, K. S.; Brewer, L. *Thermodynamics;* 2nd ed.; New York, NY: McGraw-Hill International Student Edition, 1961; pp. 95.

[34] Bent, H. A. *The Second Law;* New York, NY: Oxford University Press, 1965; pp. 55-57.

[35] Clausius, R. *The Mechanical Theory of Heat: With its Applications to the Steam-Engine and to the Physical Properties of Bodies*; John van Voorst: London, UK, 1867.

[36] Gislason, E. A.; Craig, N. C. Criteria for Spontaneous Processes derived from the Global point of view. *J. Chem. Educ.* 2013, 90, 584–590.