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Entropy and Christianity

When asked what the greatest achievement of thermodynamics is, typical students in the chemical sciences would probably all give the same answer: conservation of energy. This is a reasonable answer because the first law of thermodynamics is not only the most basic fundamental principle in the chemical and other sciences but also because it concerns energy, a concrete concept with well-understood properties. However, in the chemical sciences, in addition to energy, there is another important but more difficult to understand thermodynamics concept: entropy. Because entropy is an abstract quantity closely related to order and disorder, and to degrees of freedom, it suggests some analogies with Christianity.

Interpreting Entropy

Interpretation of entropy depends on whether we consider an object or a system from a macroscopic or a microscopic point of view.

A macroscopic view: Entropy, like other quantities (volume, pressure, and temperature) that are inherently important for describing a system, is also a state property; for a given system in a given state, the entropy is always the same, regardless of the path used to reach that state. Discovery of the state function entropy probably originated from the relentless scientific pursuit of scientists to find unchanging quantities to distinguish from numerous process-dependent variables. The first law may have created a challenge at the back of scientists' heads, urging them to find some conserved quantity that like energy, depends only on the state of the system, namely, independent of any physical or chemical process used to attain that state. Scientists knew long ago that the heat (Q) needed to bring a body from state 1 to state 2 depends on the path. However, in the mid-nineteenth century, Clausius showed that the quantity $\int_1^2$ dQ/T is independent of the path used to go from initial state 1 to final state 2, provided that the process is reversible. Thus, the change in entropy S(2)-S(1)= $\int_1^2 (dQ/T)$ becomes the macroscopic definition of entropy.

A microscopic view: In the 1870s, Ludwig Boltzmann proposed a statistical interpretation of entropy S=klnW, where k is the Boltzmann constant and W is the number of possible microstates[1] in a given system.[2] For a state at fixed temperature, fixed volume and fixed number of particles, when W is small, we have partial order; when W=1, we have complete order; when W is large, we have disorder.

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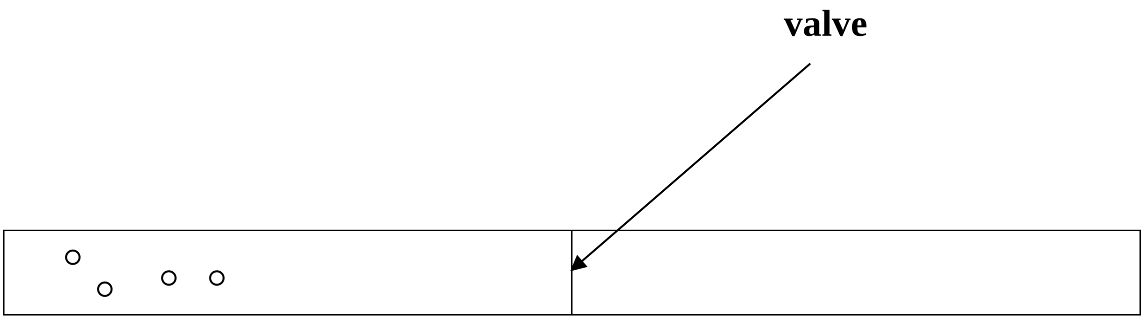
[1] A microstate is one of the huge number of different accessible arrangements(positions and velocities) of the molecules corresponding to a particular macrostate. A macrostate always contains a sufficiently large number of molecules to measure its volume or pressure or temperature, in "bulk".

[2] J.D. Fast, *Entropy*, 1962, New York Press



Consider a container that is separated into two compartments by a valve. Both compartments have the same volume. When the valve is closed, the left compartment contains 4 identical molecules, and none in the other. If the valve is open, what is the final state? From the macroscopic perspective, in the final state, two molecules are on the left and two are on the right. However, the macroscopic final state is only the most probable state; it is possible that in the final state 3 molecules are on the left and 1 is on the right. Because such “unusual” states occur with small probability; they are less likely to happen. The power of the microscopic view is that when we talk about macroscopic substances, (e.g. one mole of water or one kilogram of oil) the probability of the most probable state is much, much larger than that of any other state. Therefore, for most purposes, we can neglect all other states. The overwhelmingly large probability of the most probable state bridges the gap between the macroscopic and the microscopic points of view.

The second law of thermodynamics says that the entropy of an isolated system will never decrease. More precisely, the law should say: in the overwhelming majority of identical isolated macro systems, the entropy will spontaneously increase to a maximum, while in only a negligibly small number of systems will the entropy decrease.

Entropy and Christianity

At first sight, the scientific concept entropy may seem to be irrelevant and inapplicable to religion or to any subject other than the natural sciences. Nevertheless, some authors have related entropy to a variety of non-science subjects, in particular, to Christianity.

In the second half of the nineteenth century, a fierce debate concerned the scientific proof of the existence of God. Shortly after the second law of thermodynamics was formulated, this debate was conducted by both scientists and non-scientists. The debate was triggered by Helmholtz, who first pointed out the scenario of heat death. For a closed system, Helmholtz claimed that, because all the high-level energy (energy that can be used to produce mechanical work) will eventually be downgraded to low-level energy in the form of heat, “all possibility of a further change would be at an end, and the complete cessation of all natural processes must set in”, indicating an eternal rest of the entire universe, called the heat death of the universe.[3]

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[3] Hermann von Helmholtz, “On the Interaction of The Natural Sciences[1854],” in Science and Culture: Popular and Philosophical Essays, edited by David Cahan(Chicago and London: University of Chicago Press,1995),pp.

In the debate, people were mainly interested in the following two questions: (1) Does the second law of thermodynamics imply that the universe has both an end and a beginning? (2) Can the existence of God be proved by implication of the second law of thermodynamics when applied to the entire universe?

In response to these questions, we can identify four groups of people, each representing a particular school of thought. The first school, populated by leading British Christian physicists including Thomson, Maxwell and Tait, generally held the belief that the universe has an end and a beginning. They used the argument that Clausius made in a paper of 1868: when the second law of thermodynamics is applied to the universe, the universe will come to an end when the entropy of the entire universe reaches a maximum.[4] These physicists used the "proof by contradiction", an argument from logic to prove that the universe has a beginning. They said, if we postulate that there was no beginning to the universe, then the universe would have already existed an eternity. In that case, the entropy of the universe would already have reached its maximum, indicating that the universe must now be dead, because an infinite amount of time had passed. However, since this is clearly not the case, we have a contradiction proving that our postulate is wrong. Thus, the universe must

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[4] R. Clausius, "On the Second Fundamental Theorem of the Mechanical Theory of Heat", Philosophical Magazine 35(1868),405-419, on 419

have a beginning.

As Christian physicists, they found that beginning and end of the universe matched perfectly with the biblical message of a created world. Because the universe had a beginning, it had to be created. They asserted that the second law indicates that the world was indeed created by God.

The second school of people, mainly socialists, materialists and atheists, however, objected to both of the arguments given by the first school. They argued that the second law of thermodynamics could only be applied to a system which contains a finite number of discrete particles because they believed that every scientific experiment ever done is confined to a finite system; no experiment has ever shown that the second law can be applied to an infinite system. In this sense, their logic was that unless we have experimentally demonstrated that something is true, we can never assert that it is true. Meanwhile, assuming that the universe was infinite, they believed that it is invalid to apply the concept of entropy to the entire universe. Therefore, they refused to accept that the existence of God was proved via the entropy argument by the first group of scientists.[5] They stuck to their view that the universe was eternal.

The third group was led by Austrian physicist and philosopher Ernst Mach. He did not believe in God; he had a strong hostility towards the

[5] Raymond J, Seeger, "On Humanistic Aspects of Entropy," Physics 9(1969), 215-234; Helge Kragh, Matter and Spirit in the Universe Scientific and Religious Preludes to Modern Cosmology(London: Imperial College Press.2004), pp.50-69

Christian religion.[6] Compared to arguments by the second school, Mach's argument was more convincing because, unlike the second school of thought, he did not presuppose that the universe is infinite, making it harder for the first school to find a good counterargument. He attacked the argument of the first school by calling attention to the root problem of how we interpret time and pointed out that one object alone is insufficient for measuring time; to measure time we need at least two independent objects. Therefore, we cannot measure the rate of entropy production in the universe.

To achieve a better understanding of Mach's opinion, we need to gain a deeper insight into how he interprets time. Indeed, Mach is the first person who critically commented on Newton's view of absolute space and absolute time. While Newton believed that time is something that passes uniformly without regard to whatever happens in the world, Mach pointed out that time has no meaning until we have a reasonable way to define time. The only proper way to define time is to provide the measurement of time. To measure time, we must have a reference or a standardized time unit. We measure any time interval by comparing the time we want to measure to a reference, that is, to a standardized unit of time. To Mach, time is meaningless unless it can be measured by comparison to a reference. Only such comparison determines the meaning

[6] John T. Blackmore, Ernst Mach: His Work, Life, and Influence(Berkeley: University of California Press,1972),pp.235,290-292.

of time.[7]

Mach pointed out that when we say that the entropy of a closed system tends towards a maximum, we implicitly assume that we have a way of measuring time because the process where entropy tends towards a maximum is not instantaneous. Mach believed that we can only accurately record the process of entropy change within some part of the universe because we can find another part of the universe to serve as a clock. He pointed out that it would be meaningless to apply the second law to the entire universe because we cannot find any part outside of the universe to serve as a clock and thus, "For the universe as a whole there is no measure of time."[8]

The fourth group was mainly comprised of some Catholic physicists; among them French physicist Pierre Duhem was the most famous. Although he was a Catholic physicist, he strongly criticized the argument that the second law be employed to back up Christian faith. To counter the argument that entropy tends towards a maximum implies the ultimate death of the universe, he pointed out that although entropy does increase endlessly in the entire universe, no law from science implies any lower bounds or upper bounds on the total entropy that the universe could

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[7] *Dictionary of History of Science*, --Mach; Bynum, W. F. (William F.),Princeton University Press,1981. Mach's critique of Newton's absolute time had a profound influence on Einstein's development of his theory of relativity.
[8] Ernst Mach, Die Geschichte und die Wurzel des Satzes von der Erhaltung der Arbeit(Leigpzig: J.A. Barth,1909),pp.36-37.

sustain.[9] Thus, because entropy could vary from minus infinity to plus infinity, why could not time have the same property?

Although Duhem did not use the entropy argument to prove the existence of God, he adhered to the Catholic faith. However, unlike most Christian scientists, he was an active Christian advocate who firmly disqualified the use of science to support belief in some religion[10]. At the same time, he rejected the idea that scientific explanations be employed to serve as counterarguments to belief in religion. He believed that faith in some religion should only be based on faith itself and nothing else, and that research in physics and other sciences should be considered on its own merits, independent of religion. In an era where most distinguished scientists were making every effort either to connect the entropy argument to Christianity or to disconnect the entropy argument from Christianity, Duhem adhered to his personal philosophy that matched the purpose of a neoscholastic institute: "to form, in greater numbers, men who will devote themselves to science for itself, without any aim that is professional or directly apologetic".[11]

[9] Pierre Duhem, La theorie physique, son objet,sa structure(Paris: Chevalier et Riviere, 1906); translated by Philip P. Wiener as The Aim and Structure of Physical Theory(Princeton: Princeton University, 1954; New York: Atheneum, 1974)

[10] In this context, he harshly criticized some scientists who used the second law of thermodynamics to justify creationism and intelligent design. Creationism indicates that the world was created by some almighty being. Intelligent design indicates that, instead of a random process, evolution is always directed in some predetermined direction by a superhuman intelligent being that we call God.

[11] Desire Joseph Mercier, Address of 1891, quoted in Maurice de Wulf, An Introduction to Scholastic Philosophy(New York: Dove Publications,1956),p.270.

Conclusion

One can readily see in R.Emden's words the significance of entropy: "As a student, I read with advantage a small book by F. Wald entitled "The Mistress of the World and her Shadow". These meant energy and entropy. In the course of advancing knowledge, the two seem to me to have exchanged places. In the huge manufactory of natural processes, the principle of entropy occupies the position of manager, for it dictates the manner and method of the whole business, whilst the principle of energy merely does the book-keeping, balancing credits and debits".[12]

In addition to being fully manifested in "natural processes" as said by Emden, entropy may also add insight into our understanding of order and disorder. From the third law we know that because absolute zero can never be reached, W(S=klnW) will never be 1. This implies that order is only a special case of disorder that dominates our universe. We may be convinced, from both the entropy argument and its various applications to a variety of fields, that disorder rather than order determines the eternal rhythm of the song played by the universe.

[12] *R.Emden, Nature* 141, pp 908(1938)