Reconsideration of Boltzmann Formula and the Second Law of Thermodynamics

Yong Duan

College of Engineering, China Agricultural University, Beijing, China

Keywords: system theory; thermodynamics; Boltzmann Formula; the second Law of thermodynamics; evolution

Abstract: Now the Boltzmann Formula is not well understood. The direct meaning of this formula is, entropy increasing represents the increasing number of complexion, while entropy decreasing represents the broken of symmetry. Two deductions can be made from it. First, complicating the structure is entropy decreasing, while the simplification of structure is entropy increasing. Second, in a solitary system, a complex structure is difficult to occur and easy to be destroyed. Prigogine holds that negative entropy can only come from the world outside the system, which cannot explain the evolution of the world. The state when the chemical force is zero is a steady state, not a balanced state, because the decreased entropy and complicated system may have completed. Universal gravitation, electromagnetic force, strong interaction and weak interaction can destroy the Boltzmann Formula and the Second Law of Thermodynamics. So the world will evolve forever. Every property of substance and people's intelligence may be the force that promotes the world to develop towards complication and non-equilibrium. Complicated systems have more properties than simple ones, and it is easier for them to make positive and negative feedbacks. Therefore, the evolution of complicated system is faster than simple ones.

1. Introduction

Can the world continue to evolve? Will the world eventually go to the state of heat death? What is the driving force behind the evolution of the world? These issues have always been debated in the scientific community because of the lack of a breakthrough theorem. Let's start with the Boltzmann Formula.

2. Boltzmann Formula and Its Inferences

The Second Law of Thermodynamics is also called the Entropy Increase Theorem. Entropy has three definitions: the Clausius Theorem, the Boltzmann Definition and the Information Definition.

Boltzmann's tombstone locates at the Central Cemetery of Vienna. Without any epitaph, there is only one formula engraved on tombstone: "S = klogW" (the more precise form should be "S = klnW"). This formula has become one of the most important formulas in physics. [1] But physicists' understanding of this formula is not clear and in-depth. What conclusions can be drawn from this equation, and what misunderstandings are implied?

The breakage of symmetry is the asymmetry of system structure. For example, if there are two small balls in a box, their distribution will have only one possibility. If there are two small balls in two adjacent boxes, and the two balls are distinguishable, after the partition in the middle of the two boxes removed, the state of one side will be symmetrical and there will be two possible distributions. Let the number of balls on the left side be N1, and the number of balls on the right side be N2. When there is one ball on each side, N1 = 1. There is only one possible distribution of the two states that there are two balls on the left (N1 = 2) and there is no ball on the left (N1 = 0), both of them are symmetry-breaking states. W is the number of distribution states of N1 and N2, and is called as the number of complexion. When the ball is a gas molecule or other micro-particles, W is called the number of micro-states corresponding to a macro-state.

The Boltzmann Relation S = klnW can also be called as the Boltzmann Ordering Principle,

  DOI: 10.25236/iwmecs.2019.004

where S is the entropy of the system, K is the Boltzmann constant, and W is the number of micro-states or the number of complexion. So the direct meaning of Boltzmann's ordering principle is that the increase of entropy represents the increasing number of complexion; the state with large number of complexion is the equilibrium state (also known as structural equilibrium state). States with broken symmetry have small numbers of complexion, so the decrease of entropy represents the breakage of symmetry; the breakage of symmetry is the non-equilibrium state of structure. The Boltzmann Relation reveals the microscopic mechanism of the second law of thermodynamics. The source of energy balance is the structural balance, and the source of energy imbalance is the breaking of structural symmetry. Since symmetry breaking is complexity, the following inferences are obtained.

The First Inference of Boltzmann's ordering principle: The complexity of structure is the decrease of entropy; the simplification of structure is the increase of entropy.

The second law of thermodynamics holds that no change in an isolated system can lead to the decrease in the total value of entropy. That is, the entropy of the system always tends to increase. The Boltzmann Relation shows that the decrease of entropy represents complexity and the breakage of symmetry, and the increase of entropy represents the breakage of complex state. Therefore, the following conclusion can be drawn.

The Second Inference of Boltzmann's ordering principle: the complexity of isolated systems can only be reduced; it cannot be increased.

3. Contradictions between Boltzmann's Ordering Principle and the Second Law of Thermodynamics

Although these two inferences were not put forward in the past, these inferences represent the ideas of many people. They believe in the theory of the heat death of the universe: the world can only degenerate and cannot evolve; the universe will eventually go to heat death.

The idea of heat death of the universe was first put forward by Kelvin and Clausius, [2] but their conclusions only include the energy balance, and are exclusive of the material balance. After Einstein put forward the mass-energy relationship, this problem should have been solved. As long as there is material imbalance, there will always be the possibility to create energy imbalance. Only the second inference of Boltzmann's principle can lead to the conclusion of the heat death of the universe.

In the previous example, if the number of balls changes from two to four, the number of complexity of the equilibrium state will change from two to six. If there are 20 balls, the number of complexity of equilibrium state is 184756. [3] The larger number of complexity of equilibrium state means the smaller capacity of non-equilibrium complex structure and the smaller probability of complex structure to appear. For biological systems, the numbers of complexity of equilibrium state are very large, so the existence of complex structure of biological system means serious symmetry breakage and serious entropy reduction; the probability of biological structure appearing is very small.

Concepts like entropy increase and irreversibility shocked people and challenged traditional ideas. But they soon became a classical theory with a lofty position. The inferences of the second law of thermodynamics and Boltzmann's ordering principle are applied to many other fields, including particle movement, information transmission, interpersonal relationship, organizational development, economic development, social evolution, world evolution and so on. Systematic degradation in these areas is often regarded as an absolute tendency, since they belong to entropy increase.

However, when people push it to the extreme, the limitations of these inferences are exposed. In the process of biological evolution, organisms developed from simple single cells to complex and diverse organisms; non-living things and human societies also experienced an evolutionary process from simple to complex. If the second inference of Boltzmann's ordering principle can be applied to all material systems, the whole world will inevitably degenerate and die. Fortunately, what we see are the evolution of the world, the evolution of material systems on earth, and the

evolution of the whole universe. For a long time, the criticism of the "heat death theory" rises one after another from scientific and philosophical points of view. But most of these criticisms fail to hit the key point and lack persuasion.

The Boltzmann ordering principle implies a premise: the existence probability of each micro-state is the same, so the existence probability of the distribution with large number of micro-states is also large. This means that complex material structure is not easy to produce. This conclusion seems to be further confirmed by linking the number of micro-states with the entropy.

Seemingly, these two inferences are ineviTable deductions of Boltzmann's ordering principle and the second law of thermodynamics, but the second inference is actually wrong. The premise of Boltzmann's ordering principle does not hold under any conditions. The world has the tendencies of spontaneous degradation and spontaneous evolution. How to explain the evolution of the world?

In 1871, J. Maxwell designed a hypothetical existence, the Maxwell's Demon, to explain the evolution of the world in Limitation of the Second Law of Thermodynamics, the last chapter of the book Thermal Theory. [2] But Maxwell failed to explain the evolution of the world, because it must consume external information when making imbalances.

Prigogine believed that the entropy reduction could only come from the world outside the system. But if this is the case, considering the whole universe as a system, there will be only increase of entropy; the universe will inevitably move towards the most balanced state. In fact, at the beginning of the universe, the state after the Big Bang is the state of heat death. Today's universe comes out of the heat death state step by step, which is the result of the constant decrease of entropy. After the Big Bang, all kinds of particles came into being. No matter how short the process of producing the first kind of particles was, it was the process of particle producing from scratch. After the Big Bang and before the creation of particles, the universe was in the state of heat death. Clausius said that if the universe entered a state of heat death, no further change would take place, and then the universe would enter a state of eternal silence. [4] But in fact, the universe went out of the heat death easily without introducing any negative entropy from the outside world. The universe not only manufactures its own negative entropy, but also generates new particles, as well as new material and energy symmetry breakage. The structure of the universe is becoming more and more complex. So Prigogine's view is contradictory to the history of the universe. Moreover, the dissipative structure theory cannot explain the local concentration of negative entropy.

Although Hawking introduced the theory of the Big Bang in the Brief History of Time in detail, he believed, like Prigogine, that negative entropy could only come from the outside of the system. "The progress of human understanding of the universe is the establishment of a small orderly corner in a disorderly increasing universe." [5]

4. The Driving Force of World Evolution

Is there a Maxwell's demon that does not consume energy and external information? Yes. Imagine there is one oxygen atom on each side of a box with a partition. After the partition is removed, if the two oxygen atoms obey the second inference of Boltzmann's ordering principle, they will not stay on the same side of the box stably at the same time; there will always be one atom in each side. But in fact, there certainly won't one atom in each side; they will quickly combine to form an oxygen molecule. That is to say, the state with the largest number of complexity is not sTable; symmetry breakage occurs spontaneously. This symmetry breaking does not consume energy or external information, that is, it does not need external input negative entropy; it is a spontaneous process of entropy reduction.

What force denies the second inference of Boltzmann's ordering principle? It is the chemical bond. Chemical bond is the Maxwell's demon. It can distinguish different atoms. The chemical bond of oxygen atom "knows" other oxygen atoms; it also "knows" hydrogen atoms, iron atoms and other atoms. Chemical bond contains information and negative entropy, but the information is not input from the world outside the system, nor is it intelligent.

There are no electromagnetic forces between gas molecules, so they tend to be balanced. But liquids and solids are different. The charge of water molecules is polarity. Other liquids and solids

also rely on electromagnetic force to gather molecules together. When the temperature is high enough, the molecule will break free and become gas. When you place several molecules of liquid water on one side of the box, they do not spontaneously distribute evenly on both sides. That is to say, the number of micro-states in equilibrium state is zero, and the system will always maintain the state of symmetry breakage.

Chemical bond is an electromagnetic force. In addition to electromagnetic force, gravitation, strong interaction and weak interaction can also destroy the second inference of Boltzmann's ordering principle. They are also Maxwell's demons. We can divide the space around the earth into several grids, one of which is occupied by the earth. The earth is made up of many substances, which are not evenly distributed in these grids, but gathered together. From the perspective of the number of complexity, the probability of this state is almost zero. What force raises its probability of existence from zero to 100 percent? It's gravity.

Li-zhi Fang points out that the expansion of the universe will lead to the appearance of temperature difference, and the expansion of the universe is the result of gravitational theory, so the combination of gravitational theory and thermodynamics can explain the evolution of the world. Another reason is that the heat capacity of self-gravitation system is negative; the coexistence of negative heat capacity material and positive heat capacity material will lead to the continuous expansion of temperature difference. [6] But Li-zhi Fang only sees the effect of gravitation on heat, without considering the effect of gravitation on the distribution of matter; he does not consider electromagnetic force, strong interaction or weak interaction, either. Because evolution is complexity, [7] the following theorem can be obtained.

Theorem: Gravitation, electromagnetic force, strong interaction and weak interactions are the driving forces for the world to evolve towards a complex and non-equilibrium direction.

With this theorem, we can see that the entropy reduction can come not only from the world outside the system, but also from the inside. The second law of thermodynamics will not make the world go to the state of heat death.

The ideal thermodynamic state does not exist in the real world. Any substance has many attributes, including these four forces and many other attributes. These attributes will more or less affect the results of system movement and interaction, and promote the emergence of complex and unbalanced systems. In addition to chemical properties, all physical properties include abiotic radiation, luminescence, kinetic energy conservation, quantum mechanical properties, van der Waals force, all biological properties include growth, metabolism, regeneration, phototaxis, reproduction and variation, as well as human wisdom and social attributes such as curiosity, pursuit of honor, willpower, jealousy and laziness also promote the world to evolve toward a complicated and unbalanced state, since they can all bring about the breakage of sTable symmetry. In short, in the process of understanding the world, all attributes of the material system we found may be the driving force for the world to evolve towards a complex and unbalanced direction.

Theorem: All kinds of properties of matter may be the driving force for the world to evolve towards a complex and unbalanced direction.

The world is often in a sTable state, and there are also frequent evolutions and degenerative transitions. There are many reasons for these changes; the most important factors are the effects of positive and negative feedbacks. New negative feedback can make the system produce new sTable functions; new positive feedback can make the system appear new mutations, including the creation of life. [8] So complex systems evolve faster than simple systems.

5. Conclusion

In the process of evolution, organisms produce various organs and functions. Brain is one of these organs; intelligence is one of these biological functions. All biological functions can be the driving force of evolution; intelligence can also be the driving force of evolution. Now intelligence has become the most important force to create orders.

References

[1] R. Feng, S.T. Feng, the World of Entropy, Science Press, Beijing, 2006.

[2] Y.L. Zhou, A new discussion on the doubtful theory of “heat death of the universe”, J. Journal of Dialectics of Nature. 1 (2003) 62-69.

[3] H.Y. Wang, University Fundamental Physics, Higher Education Press, Beijing, 2000.

[4] R. Clausius, On the Second Law of Thermodynamics (Speech delivered at the 41st German Conference of Natural Scientists and Doctors, Frankfurt, on September 23, 1867), J. Natural Sciences Contend. 1 (1975) 74-75.

[5] S. Hawking, M.X. Xu, Z.C. Wu (Trans.), A Brief History of Time (Illustrated Version), Hunan Science and Technology Publishing House, Changsha, 2002.

[6] L.Z. Fang, Why does the universe not die of heat, J. Studies in Dialectics of Nature. 1 (1988) 15-21.

[7] Y. Duan, Self-organizing Life Philosophy, China Agricultural Science and Technology Press, Beijing, 2009.

[8] Y. Duan, Definition of life as well as the sufficient and necessary conditions for the origin of life, J. Journal of Hehai University (Philosophy and Social Sciences Edition). 4 (2006) 13-16.