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Article

Entangled States, Self-assembly, Condensed Matter Physics and Possible Entropy Decrease

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Abstract: First, entropy decrease in isolated system is proposed due to internal interactions. Second, we discuss entangled states and possible entropy decrease. Many entanglements are all interactions. The deterministic macroscopic entanglement is observed directly in 2021. Third, we propose that entropy decrease exists necessarily in self-assembly as isolated system. Fourth, we research various possible entropy decreases in condensed matter physics, which includes phase transformation from disorder uniformity to order state. Fifth, the solidification forms spontaneously an order structure, and it may be process of entropy decrease. Finally, we discuss the molecular motor and some other preconditions, in which entropy decreases possibly.

Keywords: entropy, internal interaction, entangled state, self-assembly, condensed matter, solidification, molecular motor.

1. Introduction

There is no doubt that the second law of thermodynamics is a great contribution to the development of science. Great scientist Eddington said: “The law that entropy always increases holds, I think, the supreme position among the laws of Nature.” But, science is a developing process. We should research other preconditions of entropy increase. Carnot law describes efficiency of heat engine, which is based temperature. Now some new engines, for example, efficiency of computer and molecular motor, etc., are not dependent of temperature. Entropy S=Q/T is dependent of temperature, which is macroscopic concept. Usual second law of thermodynamics is mainly applied to macroscopic regions.

It is probably unsuitable for Brownian movement which seems to be analogy with a perpetual motion machine, and when microscopic internal energy (for example, chemical energy, nuclear energy, etc.) is transformed to macroscopic energy, the entropy decrease is all possible.

It is known that the basis of thermodynamics is the statistics, in which a basic principle is statistical independence: The state of one subsystem does not affect the probabilities of various states of the other subsystems, because different subsystems may be regarded as weakly interacting [1]. If various internal complex mechanism and interactions cannot be neglected, a state with smaller entropy will be able to appear under some conditions. In these cases, the statistics and the second law of thermodynamics are different. We proposed that a necessary condition of entropy decrease in isolated system is existence of internal interactions [2,3]. The internal interactions often are related to nonlinearity [2]. If interactions, fluctuations and their magnified exist among various subsystems of an isolated system, entropy decrease in the isolated system is possible, which includes physics [4-7], chemistry [8,9], biology [10-12], economics and social sciences [13-15], etc. A classic example of belief on entropy increase is negative temperature, which as a measurement of molecular motions, how can it be negative? We found that negative temperature is contradiction with some basic concepts of physics and mathematics, and derives necessarily entropy decrease [4].

We proposed that the infinite gravitational collapse of any supermassive stars should pass through an energy scale of the grand unified theory (GUT). After nucleon-decays, the supermassive star will convert nearly all its mass into energy, and produce the radiation of GUT. It may probably explain some ultrahigh energy puzzles in astrophysics, for example, gamma-ray bursts (GRB), etc. This is similar with a process of the Big-bang cosmology with a time-reversal evolution in much smaller space scale and mass scale. In this process the star seems be a true white hole. Various possible entropy decreases in astronomy are discussed, for example, in the evolution of celestial bodies. We researched the singularity of black hole and Big-bang cosmology, in this point the quantum fluctuation exists necessarily [16].

So far, research on black hole entropy is based on some similarities and the belief of the second law of thermodynamics. The area increase theorem is only a necessary evolutional direction of back hole, and is independent of thermodynamics and statistics. Black hole is a simplified and order process, in which entropy should decrease and it is opposite to gas diffusion with entropy increase, and is also the biggest internal interaction. Black hole cannot be an isolated system, and thermodynamics of black hole should be the theory of dissipation structure, whose entropy decreases possibly. Further, this is impossible that both contrary collection and evaporation of black hole are all entropy increase. For opposite black hole and white hole, one is entropy increase, so another must be entropy decrease [17].

A well-known development of thermodynamics is the theory of dissipative structure proposed by Prigogine. We researched possible entropy decrease in isolated system for various complex systems [2-17], and proposed a universal formula for any isolated system [3]:

$$dS = dS^a + dS^i . \quad (1)$$

It is symmetry with the formula:

$$dS = d_i S + d_e S , \quad (2)$$

in the theory of dissipative structure. From this we derived a complete symmetrical structure on change of entropy:

$$Entropy \rightarrow \begin{cases} increase. \\ decrease \rightarrow \begin{cases} \mathrm{dS} = \mathrm{d_i}S + \mathrm{d_e}S. \\ dS = dS^a + dS^i. \end{cases} \end{cases} \quad (3)$$

Here entropy decrease may be the dissipative structure for an open system, or be the internal interactions for an isolated system [6,15]. In this paper we research various possible entropy decreases on entangled states in which internal interactions exist, on condensed matter physics which should include phase transformation from disorder uniformity to order state, and on self-assembly entropy decrease exists necessarily.

2. Entangled States and Possible Entropy Decrease

Based on the Einstein-Podolsky-Rosen (EPR) correlations and Bell inequalities, new experiments validated that quantum mechanics possesses the nonlocality and entangled state, etc.

Aspect, et al., first realized EPR experiment by the measure on the linear-polarization correlation of pairs of photons emitted in a radiative cascade of calcium and time-varying analyzers, and it agrees with the quantum mechanical predictions and the greatest violation of generalized Bell inequalities [18,19]. Ghosh and Mandel demonstrated the existence of nonclassical effects in the interference of two photons [20]. Further, the entangled state evolves a great hotspot in physics. Kavassalis and Noolandi discussed a new view of entanglements in dense polymer systems, which predict a geometrical transition from the entangled to the unentangled state in agreement with experimental data [21]. Horne, et al., discussed two-particle interferometry, which employs spatially separated, quantum mechanically entangled two-particle states [22]. Mermin discussed extreme quantum entanglement in a superposition of macroscopically distinct states [23]. Hardy investigated nonlocality for two particles without using inequalities for all entangled states except maximally entangled states such as the singlet state [24]. Goldstein provided a proof on Hardy theorem [25]. Kwiat, et al., reported new high-intensity source of polarization-entangled photon pairs with high momentum definition [26]. Strekalov, et al., reported a

two-photon interference experiment that realizes a postselection-free test of Bell inequality based on energy-time entanglement [27].

Based on some researches on EPR, we proposed that the entangled states possess the superluminal, so they must obey the generalized Lorentz transformation (GLT) with superluminal in the complete special relativity [28,29], and have some characters as the spacelike vectors. Further, it changes the phase of the entangled field, whose phase particle (phason) has some characters and corresponding equations. It is tachyon, and assume that it is similar to photon and J=1 and m=0 or mass is very small as similar neutrino, and may show the action at a distance. We researched that this field as wave has some characters, and discussed the superluminal quantum communication by a pair of entangled states is generated on both positions, or by preparing and transmitting a pair of entangled instruments, so the superluminal quantum communication. Manipulation for one position can pass the same message or information to the other, so we may implement the superluminal communication. Assume that the entangled field has a similar magnetic theory, which may be a quantum cosmic field, or be the extensive quantum theory, or God or the Buddha fields and so on. These are all macroscopic fields, which correspond to de Broglie-Bohm nonlinear "hidden variable" theory, but it is microscopic. In a word, study and application of nonlocality and entangled field have important scientific and social significance [30].

The entangled states exhibited new interactions, which break through the natural inherent stochasticity of current quantum mechanics, which is completely or approximately completely independent of each other. Interactions are related to the nonlinear quantum theory [31]. Therefore, the basis of quantum mechanics must be modified. From macroscopic to microscopic observations and measurements new properties of entanglement production also introduce the scale of new interactions.

The entangled states have wave properties, and will be relatively condensed. Entanglements are often described in quantum mechanics by superposition states, and form the entangled fields. This also corresponds to microscopic general relativity, where the set of particles, i.e., entangled fields determine the space-time. It can be combined with the mechanical wave theory [32], and solve the equations, and derive the interference of wave, etc.

We defined the entangled scale, which mainly involves the number n and entangled degree. Since coherence, entanglement and correlation are all internal interactions in information systems, we discussed quantitatively entropy decrease along coherence, and entropy increase only for incoherence. From beginning quantum heat engine, we must systematically study quantum thermodynamics and entropy. Based on some astrophysical simulation models, they shown that the universe evolves from disorder to structures, which correspond to entropy decrease. This is consistence with theoretical result. The simulation must be an isolated system only using internal gravitational interactions [33].

The nature of interference and diffraction lies in coherent superposition. If coherent is the entropy decrease, the wave interference and diffraction as coherent will be entropy decrease. The intensity distribution of the double-slit interference is:

$$I_{12} = |h_1 + h_2|^2 = |h_1|^2 + |h_2|^2 + (h_1 h_2^* + h_2 h_1^*) = I_1 + I_2 + \text{interference term.} \quad (4)$$

If the interference term>0, the intensity will increase, regardless of Bose-Einstein statistics or Fermi-Dirac statistics. Diffraction and the coherence are the double-slit experiments. Decoherence is a single-slit, and possible entropy decrease.

For study the entropy of mixed states, soluble liquid mixed cannot separate each other, but insoluble matter mixed will be separated due to weight and interaction. If soluble is entropy increase, insoluble separated will be entropy decrease [2]. Waves can interfere, and intensity enhances or disappears, and corresponds to entanglement. For the case, the information and entropy are increase or decrease. It is related to quantum optics and quantum information, etc. Further, wave may develop to nonlinear waves.

In 2021 Kotler, et al., observed directly deterministic macroscopic entanglement, in which using pulsed electromechanics, two mechanical drumheads with masses of 70 picograms are entangled. Such entangled macroscopic systems are poised to serve in fundamental tests of quantum mechanics, enable sensing beyond the standard quantum limit, and function as long-lived nodes of future quantum networks [34].

Generally, quantum mechanics is statistical, and should have statistical independence. It seems to correspond to the linear superposition and the linear theory. Quantum entanglement should have interactions, so this and usual quantum mechanics seem to have difference, but it denying locality. Such quantum theory should be combined and modified and developed. This may correspond to the nonlinear theory and fifth interaction [31].

Further, various entanglements, from quantum entanglement to mind induction, human-nature response, interpersonal relations, are all interactions, and should decrease entropy and increase information. In sociology the stronger the entanglement, interference, habits, customs and laws, the more orderly the society is. Usual large-scale entanglement cannot be used as isolated systems. But, twins with magic entanglement may act as an isolated system.

3. Necessity of Entropy Decrease in Self-Assembly

Self-assembly(SA) is a process in which a disordered system of pre-existing components forms an organized structure or pattern as a consequence of specific, local interactions among the components themselves, without external direction. Therefore, it must be an isolated system, and is necessarily entropy decrease [7].

When the constitutive components are molecules, the process is termed molecular self-assembly. Molecular self-assembly is an autonomous process that forms molecules or polymer under non-external influence is nanostructure technology. Crane (1950) proposed two basic principles of molecular self-assembly [35].

Self-assembly can be classified by static or dynamic SA. In static self-assembly, the ordered state forms as a system approaches equilibrium reducing its free energy. In dynamic self-assembly, patterns of pre-existing components organized by specific local interactions are not commonly described as "self-assembled".

Self-assembly in the classic sense can be defined as the spontaneous and reversible organization of molecular units into ordered structures by non-covalent interactions. The first property of a self-assembled system that this definition suggests is the spontaneity of the self-assembly process: the interactions responsible for the formation of the self-assembled system act on a strictly local level, i.e., nano-structure. This arises in the strong non-equilibrium conditions. The most famous example of self-assembly is the occurrence of the life on Earth. Another example is the phenomenon of electrostatic trapping, in which an electric field is applied between two metallic nano-electrodes. The particles present in the environment are polarized by the applied electric field. Due to dipole interaction with the electric field gradient the particles are attracted to the gap between the electrodes [36]. Self-assembly of crystals works well [37].

Self-assembled monolayer and molecular self-assembled film are molecules pass through chemical bond, and interact spontaneously to form stable order film with the lowest energy [38].

Any chemical reaction drives atoms and molecules to assemble into larger structures. An important feature of SA is the key role of slack interactions. Another distinctive feature of SA is that the building blocks are not only atoms and molecules, but span a wide range of nano- and mesoscopic structures, with different chemical compositions, shapes and functionalities [39]. Recent examples of novel building blocks include polyhedra and patchy particles, and include microparticles with complex geometries, such as hemispherical [40], dimer [41], discs [42], rods, molecules [43], and multimers. These nanoscale building blocks (NBBs) can in turn be synthesised through conventional chemical routes or by other SA strategies.

Some important examples of SA in materials science include the formation of molecular crystals, colloids, lipid bilayers, phase-separated polymers and self-assembled monolayers [44,45]. The folding of polypeptide chains into proteins and the folding of nucleic acids into their functional forms are examples of self-assembled biological structures. Adleman [46], Winfree, et al. [47] and Ignatova, et al. [48] discussed the self-assembly of DNA structures by the molecular and DNA computation. Recently, the three-dimensional macroporous structure was prepared via self-assembly of diphenylalanine

derivative under cryoconditions, the obtained material can find the application in the field of regenerative medicine or drug delivery system [49].

Chen, et al., demonstrated a microscale self-assembly method using the air-liquid interface established by Faraday wave as a template. This self-assembly method can be used for generation of diverse sets of symmetrical and periodic patterns from microscale materials such as hydrogels, cells, and cell spheroids [50].

Another characteristic common to nearly all self-assembled systems is their thermodynamic stability. SA is to take place without intervention of external forces, the process must lead to a lower Gibbs free energy, thus self-assembled structures are thermodynamically more stable than the single, unassembled components. The driving force is capillary interaction, which originates from the deformation of the surface of a liquid caused by the presence of floating or submerged particles [51]. Uskoković researched that every self-assembly process in reality presents a co-assembly, which makes the former term a misnomer of a kind [52]. The thesis is built of the concept of mutual ordering of the self-assembling system and its environment. Further, we discuss the nonlinear self-assembled theory.

Self-assembly processes can be observed in systems of macroscopic building blocks, which can be externally propelled [53] or self-propelled [54]. Groß, et al., discussed self-assembly at the macroscopic scale [55].

Self-assembly is related closely to self-organization. Halley, et al., discussed consistent concepts of self-organization and self-assembly [56]. Self-organization is the non-equilibrium process where self-assembly as a spontaneous process leads toward equilibrium. Self-assembly requires components to remain essentially unchanged throughout the process. Moreover, self-organization is related to the memory alloy.

We proposed that possible entropy decrease exists in transformations of internal energy, complex systems, and some new systems with lower entropy, etc. Self-organization and self-assembly must be entropy decrease. Generally, much structures of Nature all are various self-assembly and self-organizations. We researched some possible tests and predictions on entropy decrease in isolated systems. They include various self-organizations and self-assembly, some critical phenomena, physical surfaces and films, chemical reactions and catalysts, various biological membranes and enzymes, and new synthetic life, etc. They exist possibly in some microscopic regions, nonlinear phenomena, many evolutional processes and complex systems, etc [7]. The magnetization process is more ordered, so it should be entropy decrease. So the spontaneous magnetization is namely spontaneous entropy decrease. This is an internal interaction. More generally, it is related to the thermodynamics in electromagnetism. As long as we break through the bondage of the second law of thermodynamics, the rich and complex world is full of examples of entropy decrease.

4. Possible Entropy Decrease in Condensed Matter Physics

The second law of thermodynamics must be thermal equilibrium processes, so which have not phase transformation.

We emphasize that preconditions of entropy increase are 1) for isolated systems; 2) various internal interactions in system must be neglected; 3) they must be thermal equilibrium processes. We proposed possible entropy decrease includes phase transformation from disorder uniformity to order state. The solidification forms spontaneously an order structure, and it may be process of entropy decrease. We researched entropy decrease in astronomy and proposed quantitatively a total formula of entropy change for universal evolution of any natural and social systems [57].

In various phases and phase transformations, only gas diffusion process agrees the best with the second law of thermodynamics.

Entropy of the ideal gases is:

$$S = C_V \ln T + nR \ln V + S_0 . \tag{5}$$

For an equal-temperature process T=constant,

$$dS = S_f - S_i = nR \ln(V_f / V_i) . \tag{6}$$

This decreases dS<0, when $V_f < V_i$, i.e., for the attractive process. Conversely, the entropy increases dS>0, when $V_f > V_i$. The entropy of non-ideal gases is [1]:

$$S = S_{id} + N \log(1 - Nb/V) . \tag{7}$$

This is smaller than one of ideal gases, since b is four times volume of atom, b>0. It corresponds to the existence of interaction of the gas molecules, and average forces between molecules are attractive [1]. The entropy of a solid is [1]:

$$S = 2\pi^2 VT^3 / 15(\hbar \bar{u})^3 , \tag{8}$$

so dS<0 for dT<0. The free energy with the correlation part of plasma is [1]:

$$F = F_{id} - \frac{2e^3}{3} \frac{\pi^{1/2}}{(VT)^{1/2}} \left(\sum_a N_a z_a^2 \right)^{3/2} . \tag{9}$$

Correspondingly, the entropy is:

$$dS = S - S_{id} = -\frac{e^3}{3} \frac{\pi^{1/2}}{V^{1/2}} \left(\sum_a N_a z_a^2 \right)^{3/2} T^{-3/2} < 0 . \tag{10}$$

There are electric attractive forces between plasma. Generally, entropy decreases for gravitation [2,3]. Other, celestial nebula may agglomerate stars, and liquid has the capillary flow [58].

In phase transformation, structures and symmetries are different, corresponding internal energies and entropies are also different. At a critical point of phase transformation, entropy can increase or decrease, i.e., possesses two-direction property. This corresponds to reversibility of transformation between order and disorder. The general phase transformation is an open system. But, if input energy is interrupted at the critical point, it will become an isolated system. Although for any isolated system the gravitational field cannot be screened completely, but the electromagnetic field may be screened completely.

Hwang, et al., investigated the two-dimensional growth of Au on Ru(0001) in the submonolayer range. At room temperature, highly dendritic islands of one layer thickness grow on large Ru terraces. These irregular dendritic islands exhibit a fractal character, and a dimensional analysis yields a fractal dimension 1.72±0.07, which agrees quantitatively with a two-dimensional diffusion-limited-aggregation (DLA) growth mechanism [59]. Brune, et al., studied nucleation on atomic scale for Ag deposition on a Pt(111) surface at low temperature (50-120 K), in which the transition from the initial steps of nucleation to growth and coalescence as a function of temperature [60]. Röder, et al., studied diffusion-limited aggregation (DLA) of Ag on Pt(111) and Ag(111), and found an extended range of deposition temperature and deposition flux in both metal-on-metal systems fractal growth shapes, and determined the diffusion constants for edge diffusion from a quantitative analysis of the exponential variation of the branch width with temperature [61]. Bott, et al., proposed and demonstrated a new approach for the determination of activation energy and attempt frequency for the diffusion of single adatoms on a surface for Pt adatom diffusion on Pt(111). The method is involves only a minimum of assumptions and is independent of classical nucleation theory [62].

Vvedensky, et al., discussed stochastic equations of motion for the surface of a solid that evolves under typical epitaxial growth [63]. For the growth of non-crystalline films, when cooling melt with certain rate from high temperature, its volume V, entropy S and enthalpy H decrease continuously, temperature T achieves melting point T_m, and volume, entropy and enthalpy decrease suddenly, material becomes crystal. Then volume, entropy and enthalpy of crystals decrease slowly with temperature. Moreover, in phase transformation there is the supercooling state. In usual physics the thermodynamic fluctuation do not allow that any two dimensional crystal exists as stable single under finite temperature. But, in 2004, Novoselov and Geim separated big piece monolayer graphene [64]. It shows a question for thermodynamics.

The order structure of graphene may be isolated system. Graphene has a special interacting Wigner-Seitz radii r_s (coupling constant). Experiments show electron interaction in grapheme is weak than one in two dimensional electron gas [65]. This is an internal interaction.

Supersaturated liquid phase aggregates easily film in surface. Liquid after supersaturated should be isolated system, and VdW force is also internal interaction.

Phase transformations like chemical reactions are driven by heat fluctuation [66]. Lange discussed chemical solution routes to single-crystal thin films [67]. It introduces solution with microscopic interaction. Usual chemical ways are also based on different interactions. We researched possible entropy decrease in chemical reactions [8,9].

Heat preservation and cooling may be in isolated system at least for a shorter time. Oil mixed water forms sphere (its curvature R=2/r is the biggest), and crystal are all ordered. Two interfaces in general physics possess microscopic interactions, in which the simplest tensile stress.

5. Possible Entropy Decrease in Solidification

In solidification process the solidification forms spontaneously an order structure [68]. Under certain conditions it may be isolated system of non-equilibrium process, which is possibly entropy decrease.

Configuration entropy S_c of liquid decreases along with temperature T, and describes by Adam-Gibbs relation

$$t = t_0 \exp(A/TS_c), \text{ i.e., } S_c = \frac{A}{T\ln(t/t_0)}. \qquad (11)$$

For solidification there are mixed entropy, and high entropy alloy [69,70], etc.

Non-crystal is metastable matter, which tends spontaneously to stable crystal under certain conditions, for example, high temperature cooling or supercooling. This is spontaneous entropy decrease. Two processes of alloy crystal on liquid are nucleation and growth [71], and both are all ordering. Phase-field model may be based on the free energy function or entropy function [72-74].

In cooling solid phase or liquid phase, enthalpy ΔH decreases, and $\Delta S = \Delta H / T_m$ [66]. When melting point T_m invariant, so ΔH <0, and $\Delta S = \Delta H / T_m$ <0. For microscopic structure of solidification, no matter what form of equiaxed growth or preferred crystallographic directions [66] is all ordered. The formation of spheres (the curvature R=2/r is maximum) and crystals are also ordered. Further, clusters, embryos, metastable and supercooling (undercooling), etc., should all be entropy decrease. Solidification theory discusses kinetics of atom attachment, interface kinetics and nucleation kinetics, and introduced melting entropy, crystallography of entropy and dimensionless entropy of fusion $\alpha = \Delta S_f / R$. If R is invariant, when α from small to bigger, entropy increases; contrarily, when α from big to smaller, entropy decreases. It is known that definition of classical thermodynamics cannot determine the interfacial stability in growth. Therefore, the pseudo-thermodynamics indeed is introduced [66].

The rapid solidification processing (RSP) may be realized by deep supercooling of melt, bulk supercooling, or power fabrication. In the equilibrium distribution of crystal nucleus of supercooling melt, the mixed system is composed of N atoms of liquid phase and M atomic clusters of crystal (each atomic cluster includes n atoms). By comparison of system with only atoms but without crystal nucleus at the same temperature, change of free energy is:

$$\Delta G = M\Delta G_n - T\Delta S_n . \quad (12)$$

Here ΔG_n is change of free energy in order to form a crystal nucleus with n atoms, and ΔS_n is mixed entropy with M atomic clusters and N atoms of liquid phase [66]. From this

$$\Delta S_n = (M\Delta G_n - \Delta G)/T . \quad (13)$$

If $M\Delta G_n > \Delta G$, there will be ΔS_n>0; if $M\Delta G_n < \Delta G$, so ΔS_n<0.

6. Molecular Motor and Some Discussions

Present the second law of thermodynamics uses the entropy S to identify the spontaneous changes. S is a measure of the molecular disorder of the system. But, when internal interaction in an isolated system exists, i.e., the kinetic energy is transformed to the potential energy, then the order increases, the kinetic energy and entropy decrease.

The actuator is a material capable of changing its properties according to the changing system state [75]. Modern intelligent materials are sometimes referred to as the “life of the non-living world” [76]. This may even be related to animism, and is probably made the Maxwell demon.

Cellular automata may be auto-aggregation [77,78]. Perhaps it can produce results violated the entropy increase principle [79].

It is known that the fluctuations and their amplifications can form structures, and derive order [1,58]. Such internal interactions and their fluctuations and amplifications can also lead to entropy decrease and self-organization. Usually fluctuations can derive order, and fluctuations may be origin of internal interactions in isolated system. Nebulae form stars through gravitational self-interaction. Biological evolution is also mainly self-interacting. It corresponds to nonequilibrium statistical physics of self-organization, which includes Vicsek model [80-82].

Scully, et al., designed a photonic gas heat engine [83], which violates the second law of thermodynamics on the surface, and the thermal machine efficiency may be greater than that of the Kano cycle. The existence of Maxwell demon in the quantum theory improves possibly the efficiency of the quantum thermal machines [84].

The molecular motor takes a very important role for keeping high order in biologic systems. We think, the molecular motor corresponds to dS<0, in which the chemical energy of cell translates into

mechanical energy, whose efficiency is almost 100%. In the microtubule the motor proteins have kinesin and dynein. Their moving way is hand-over-hand [85]. The kinesin moves matter of cell nucleus to cell membrane, and dynein moves matter of cell membrane to cell nucleus. Their transport direction is just opposite, but, both are not competition [86]. Moreover, many motors may work together, and produce speed with 10 time unit motor. It is namely order cooperative action [87]. In 2021, the first self-reproducing living robot (Xenobots 3.0) even was discovered.

The rotary motor is composed of biologic macromolecule, whose volume is small, and efficiency is very high almost 100%, and they may converse rotate. Its type is ATPase, which is a core enzyme for biologic energy translation in organism. The entire process of cell upgrowth and metabolism need energy, which is obtained from the chemical energy hydrolyzed by ATP under the most cases, and ATP is synthetized from ATPase. The molecular motor of ATPase may hydrolyze ATP, and may also synthetize ATP. This is similar with membrane and Maxwell demon.

7. Conclusion

The entropy of the Universe increases in all natural processes, and isolated systems tend to greater disorder [88]. Although the total entropy for whole system must be positive and increase possibly, but, so long as different entropy states for any systems exist, entropy should decrease in transformation process from a higher entropy state to a lower entropy state, for example, from chaos to order, from war to peace and so on [6,57]. If this system is isolated, it will correct and develop the second law of thermodynamics. Further, we proposed quantitatively a universal entropy theory on evolution of any natural and social systems, and corresponding total formula of entropy change [6,15,57].

The chemical reactions of periodic change, for example, Belousov-Zhabotinski reaction, must be entropy decrease for those periods of time. Generally, any periodic change should be period of entropy increase and decrease, but it never can be entropy always increase.

In a word, world is not pessimistic always. Various complex natural and social phenomena in world cannot always be processes of entropy increase.

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