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The minus thermodynamic law concept: A statement

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Abstract: Time asymmetry in thermodynamic systems, governed by the Second Law of Thermodynamics, has long been associated with the natural progression toward equilibrium, although interpretations vary widely across scientific perspectives. To address this diversity, a more comprehensive framework that encompasses both equilibrium and non-equilibrium states is essential. This paper introduces the Minus First Law as a foundational principle to expand the thermodynamic framework and more effectively account for time asymmetry. The concept enables an analysis of both symmetrical and asymmetrical states across forward and reverse temporal directions, addressing the complex interplay between the thermodynamic arrow of time and the statistical mechanics arrow. By broadening the theoretical scope, it aims to bridge gaps across macroscopic and microscopic scales, offering a unified perspective on time asymmetry within both equilibrium and non-equilibrium thermodynamic systems. Such an approach could refine our understanding of irreversible processes and deepen insights into the emergence of temporal asymmetry from microscopic dynamics.
Keywords: *Law concept, Minus first law, Thermodynamics, Time asymmetry.*

1. Introduction

The investigation of time-reversal invariance within thermodynamics has attracted considerable attention from researchers. Historically, the Second Law of Thermodynamics has been closely tied to the concept of time asymmetry, associating the rise in entropy with the journey toward equilibrium. However, a fascinating alternative viewpoint arises from another study [1,2], which calls this traditional understanding into question. This research indicates that the widely accepted belief that entropy invariably increases as a system moves toward equilibrium lacks a solid theoretical basis [3,4]. The discussion surrounding time asymmetry explores theoretical aspects more thoroughly, providing strong arguments that challenge the established framework. Specifically, the claim that the thermodynamic arrow cannot be solely linked to the Second Law of Thermodynamics implies a different source for the thermodynamic symmetry that leads to equilibrium [5,6]. Furthermore, when analyzing the partitioned states of a thermodynamic system, regardless of whether it is in equilibrium or non-equilibrium, a dynamic sense of progression is still evident [7,8]. This realization leads to the proposal of a governing principle for equilibrium alongside the established laws of thermodynamics (from the zeroth to the second law), referred to as the Minus First Law. As described in [4], this law suggests that an isolated system, beginning from any arbitrary initial state within a fixed finite volume, will naturally evolve toward a distinct state of equilibrium [9]. The fundamental idea behind this new proposition will be elaborated on in the upcoming sections.

This paper presents an innovative viewpoint on thermodynamics by introducing the Minus First Law as a foundational concept to build upon the traditional laws of thermodynamics, with a particular emphasis on time asymmetry. While earlier research has mainly focused on the Second Law of Thermodynamics in relation to entropy and equilibrium, this report proposes a comprehensive framework that takes into account both equilibrium and non-equilibrium states over time. Previous studies have largely restricted their investigations of time asymmetry to the natural progression of entropy toward equilibrium. However, this document offers a wider perspective by examining the

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arrows of time in thermodynamics and statistical mechanics concurrently, thereby emphasizing a more complex interaction between macroscopic and microscopic levels. The suggested Minus First Law acts as a conceptual link between these areas, providing a cohesive explanation of time asymmetry in both forward and reverse temporal directions, which could facilitate more sophisticated analyses of irreversible processes and the origins of temporal asymmetry from fundamental dynamics. In summary, this framework addresses a theoretical void by proposing a law that contextualizes the arrow of time outside of equilibrium states, tackling shortcomings in prior interpretations and enriching our comprehension of non-equilibrium phenomena within thermodynamics.

2. Minus First Law Proposal

The proposal can be broken down into several elements, particularly focusing on the temporally asymmetric feature known as Claim A within Wallace's framework, as referenced in [5]. This claim highlights the presence of equilibrium states in isolated systems, which are defined by their stability; once these states are attained, they will remain constant over time unless influenced by external factors. Although the Minus First Law provides a unique viewpoint on how equilibrium is established, Claim A introduces an essential aspect of time asymmetry, suggesting that this asymmetry is inherent in the conceptual framework itself. This viewpoint represents a shift from Boltzmann's traditional interpretation of equilibrium in statistical mechanics, where equilibrium is characterized by the macrostate with the greatest phase volume, a concept that is essentially time-symmetric [10]. Conversely, the thermodynamic perspective tends to focus on the irreversible processes that lead to equilibrium, resulting in a distinction between these two interpretations [7].

The discussion surrounding the Minus First Law remains inconclusive, as there is a lack of definitive proof backing the claim of temporal asymmetry, even in light of Claim A. This argument draws connections to the Second Law of Thermodynamics, particularly regarding entropy, and also considers fixed equilibrium states related to time. It indicates that the shift from non-equilibrium to equilibrium can take place in either temporal direction [11]. The idea of temporal symmetry is further explored through a concept known as the past hypothesis, which asserts that equilibrium is reached in the future instead of the past, thereby distinguishing the statistical characteristics of asymmetry [12,13]. This viewpoint recognizes that while systems progress toward equilibrium, the path followed is intrinsically time-dependent, adding complexity to the connection between time, entropy, and thermodynamic behavior [14]. A more detailed and integrative perspective on the Minus First Law will be provided in the following section, aiming to consolidate these ideas and shed light on the dynamics of equilibrium and time asymmetry.

3. Minus First Law Theory

An alternative interpretation of the Minus First Law is its relation to the Zeroth Law of Thermodynamics, which deals with thermal equilibrium through the principle of transitivity in inter-body interactions. The Zeroth Law, which is essential to the concept of temperature, states that temperature is an equilibrium-driving characteristic if two systems are in thermal equilibrium with a third, then they must also be in equilibrium with one another [15]. In his exploration of thermodynamic principles, Joseph Kestin emphasizes that temperature and its reliable measurement stem from the predictable interaction of systems through diathermal (heat-conductive) boundaries. According to Kestin in [14], this interaction, even within complex systems isolated by adiabatic (non-heat-conducting) barriers, invariably results in a stable thermal equilibrium state [16,17]. The equilibrium principle foundational to the Minus First Law can be divided into three core claims:

Claim A: In isolated systems, equilibrium states can exist, remaining spatially uniform and unchanged once established over time. This characteristic of equilibrium states indicates that the thermodynamic properties remain stable and consistent unless external factors modify the system's boundaries, permitting potential variations without external interference. This assertion highlights the spontaneous nature of equilibrium states, stressing their stability even amidst possible microscopic variations [18].

Claim B: The distinctiveness of the equilibrium state indicates that any isolated system, no matter its initial conditions, will eventually reach a unique equilibrium state. This claim suggests that the equilibrium state of each system is singular and non-reproducible, setting it apart as the final state of any internal processes taking place within an isolated system [19].

Claim C: The spontaneous shift from non-equilibrium to equilibrium occurs when internal constraints divide subsystems within an isolated system (for instance, using adiabatic walls). These partitions inhibit thermal interaction, preserving non-equilibrium conditions. However, once these barriers are eliminated, the system naturally moves towards equilibrium without any external influence, illustrating the inherent inclination of systems to stabilize as time progresses.

Claim A exemplifies time asymmetry in thermodynamics, highlighting the natural tendency of systems to move toward equilibrium [22]. This characteristic emphasizes the one-way temporal nature of thermodynamics, where equilibrium states develop independently of external factors, contrasting the time-symmetric viewpoint of equilibrium states in statistical mechanics [17]. In statistical mechanics, equilibrium is characterized as the macrostate with the greatest probability, lacking a preferred direction of time and, therefore, differing from the thermodynamic concept of equilibrium in isolated systems [11].

In certain systems, such as gases, these equilibrium principles exhibit mutual compatibility, allowing processes to occur in both directions and demonstrating the flexibility of the equilibrium approach under different conditions. Nonetheless, the Minus First Law concept offers an independent framework that aligns closely with Claim A, positing that thermodynamic systems can be considered independently of their surroundings to maintain equilibrium principles without additional assumptions beyond those provided by the Zeroth Law [23,24]. Consequently, the Minus First Law provides a cohesive foundation for thermodynamic equilibrium in isolated systems, offering a new perspective alongside the classical Zeroth Law [25].

4. Conclusion

Based on various theoretical models, differences in thermodynamic conditions across various environments lead to discrepancies in the Clausius entropy principle and those related to the Minus First Law. These variations highlight that although the principles that dictate the thermodynamic arrow of time are intricate, they are still aligned with the statistical mechanic's arrow. The foundational elements of the Minus First Law seem to advocate for an equilibrium achieved from initial non-equilibrium situations, which is consistent with the statistical mechanics view on initial conditions found in the "past hypothesis." This viewpoint suggests that the Minus First Law can coexist with systems that maintain equilibrium states in fixed conditions over time, while non-equilibrium systems inherently move toward equilibrium in both time directions. Consequently, the Minus First Law offers a more comprehensive perspective on how the thermodynamic arrow is perceived, integrating these asymmetrical behaviors with the principles of statistical mechanics. This relationship highlights a connection between classic thermodynamic laws and contemporary statistical theories, providing a meaningful explanation for the directional nature of time and enhancing the understanding of thermodynamic time asymmetry in modern physics.

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